THREE SECTIONS

Engineering Library

SECTION I

S·A·E JOURNAL

A chain is no stronger than its weakest link.

A whole is no finer than its least perfect detail.

In deference to these truisms, and before making public announcement of GYRO, we wish to again scrutinize every detail of construction and apply still higher polish wherever found possible.

GYRO

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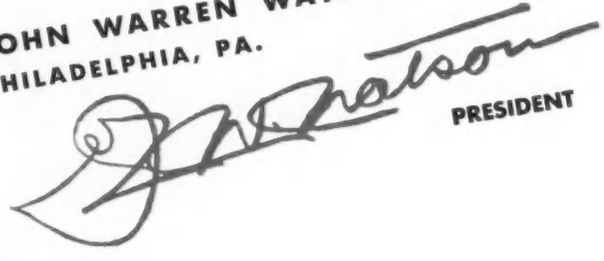

PRESIDENT

S·A·E· JOURNAL

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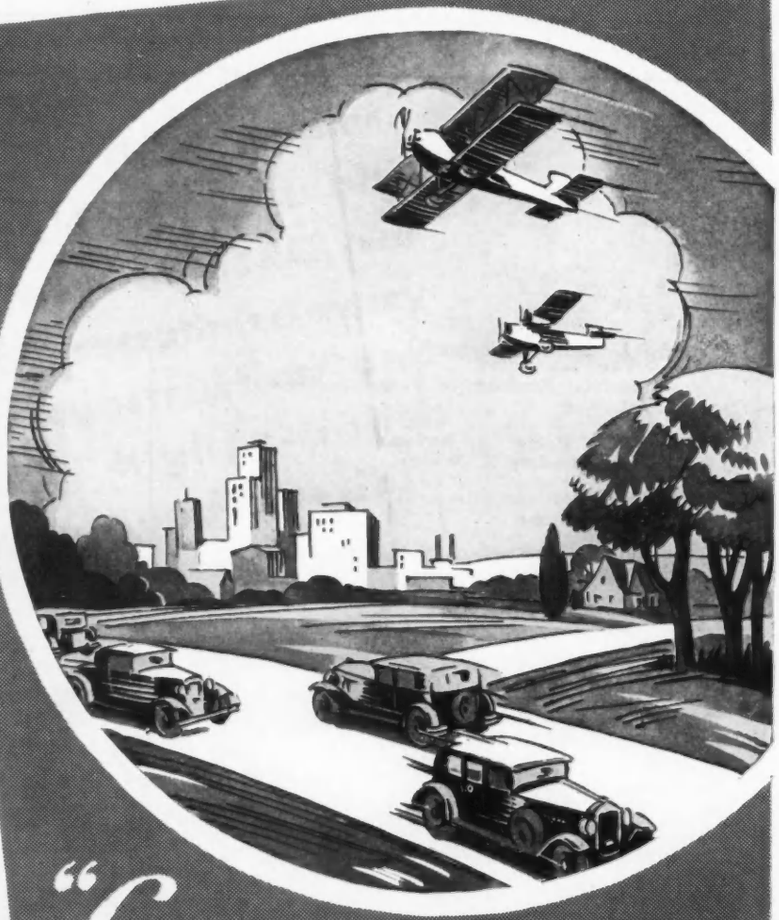
This issue consists of three Sections: Section 1, the regular issue of the S.A.E. JOURNAL; Section 2, Index to Vol. xxix, July to December, 1931; Section 3, Reports of Divisions to the Standards Committee.

The purpose of meetings of the Society is largely to provide a forum for the presentation of straightforward and frank discussion. Discussion of this kind is encouraged. However, owing to the nature of the Society as an organization, it cannot be responsible for statements or opinions advanced in papers or in discussions at its meetings. The Constitution of the Society has long contained a provision to this effect.

ON THE AIRWAYS TODAY

as on the highways for the last 30 years!



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S·A·E JOURNAL

Two Great Occasions

Willys to Speak at Annual Dinner, Jan. 14; Annual Meeting Program, for Jan. 25 to 29, Includes Notable Names

RETURNS from the Annual Dinner reservation blank, mailed to all members of the Society a fortnight ago, indicate that the Annual Dinner at the Pennsylvania Hotel, New York City, on Jan. 14, will be well attended; and the program for that event assures that the audience will be splendidly compensated for its presence.

One speaker only is scheduled to make an address. He is the Hon. John N. Willys, United States Ambassador

HON. JOHN N. WILLYS

to Poland, who has been a prominent figure in automotive circles for many years. His topic will be The Automobile Industry—Past, Present and Future. Mr. Willys will be introduced by William P. MacCracken, formerly Assistant Secretary of Commerce for Aeronautics, now a partner in the firm of MacCracken & Lee, of the City of Washington. Mr. MacCracken's ability as a toastmaster is too well known to S.A.E. audiences to require comment. The official humorist of the evening will be "Senator" Ford, whose brief talks on this and that will leave no doubt as to who's who and what's what.

Members who have not yet sent in a reservation blank should do so at once to be sure of securing a desirable place at the Dinner. If the reservation blank has been lost or mislaid, members desiring to attend the Dinner should immediately write to headquarters, 29 West 39th Street, New York City, enclosing remittance for the necessary amount. The following prices will prevail at the Dinner: Members, $5; ladies, $5; non-member guests, $6. Tables will be reserved for ladies in the balcony. Applications will be filled in the order in which they are received, and no refunds will be made or cancellations accepted after Monday, Jan. 11.

Remember Jan. 25 to 29!

Ten technical sessions, a standards meeting, a student evening, a business session and a dinner have been scheduled for Annual Meeting Week, Jan. 25 to 29, at the Book-Cadillac Hotel, Detroit, and the program printed on p. 23 has been so arranged by Chairman Shidle and the Meetings Committee that no one of the events will interfere with another. The various Activities of the Society have worked effectively in preparing the technical program, and the enthusiastic cooperation of the Detroit Section assures the success of the Student Session on Monday evening, Jan. 25, and the Dinner on Thursday evening, Jan. 28. Beginning on Monday morning with a Standards Session and concluding on Friday with a Research Session, the Annual Meeting program contains such varied fare that every member of the Society will find in it something of particular interest.

Burney on Streamlining

An outstanding paper, which for many members will be the most interesting item of the entire meeting, will be presented by Sir Dennistoun Burney, the distinguished English engineer who will come to this Country for the purpose of attending the S.A.E. Annual Meeting and telling his ideas on

WILLIAM P. MACCRACKEN

streamlining and rear engine-mounting. He expects to bring two cars with him for demonstration. His talk will be given at the Chassis Session on the evening of Tuesday, Jan. 26, and it is believed that the standing-room-only sign will be hung outside the Crystal Room of the hotel that evening.

Meetings Calendar

National Meetings

Miami Air-Race Dinner—Jan. 6

In cooperation with the City of Miami Chamber of Commerce, the Aeronautical Chamber of Commerce of America and the All-American Air Race Association.

Annual Dinner—Jan. 14

Pennsylvania Hotel, New York City

Annual Meeting—Jan. 25 to 29

Book-Cadillac Hotel, Detroit
Detroit Section cooperating as host at the Dinner and sponsoring Student Session

Motorboat Meeting—Feb. 18

A. W. A. Clubhouse, New York City
In cooperation with the Metropolitan Section

21st National Aeronautic Meeting—April 5 and 6

Detroit

Section Meetings

Baltimore—Jan. 14

Hotel Emerson; Dinner 6:30 P.M.
Lubrication—A. Ludlow Clayden, Research Engineer, Sun Oil Co.

Canadian—Jan. 20

Royal York Hotel, Toronto; Dinner 7:00 P.M.
Aeronautic Meeting—Speakers: Capt. Earl Hand and Capt. A. Roy Brown

Chicago—No Meeting

Cleveland—No Meeting

Detroit—Jan. 25 to 29

Book-Cadillac Hotel
Cooperating in Annual Meeting of the Society

Indiana—No Regular Meeting

Cooperating in Maintenance Meeting at Purdue University, West Lafayette, Ind., Jan. 7 and 8

Metropolitan—Jan. 11

Hotel Commodore, East Ball Room, New York City—Automobile Show Dinner 6:30 P.M.
Automobile Trends for 1932—Harold F. Blanchard, Technical Editor of *Motor*
Atrocities of 1932—Herbert Chase

Milwaukee—No Meeting

Northwest—Jan. ?

New Washington Hotel, Seattle, Wash.; Dinner 6:30 P.M.
In the Realm of Research—Prof. F. G. Baender, Oregon State College

Oregon—Jan. 8

Multnomah Hotel, Portland; Dinner 6:30 P.M.
Diesel-Engine Injectors—Prof. F. G. Baender, Oregon State College
Safety Methods That Pay Profitable Dividends—Representative of City of Portland Fire Department
White-Line Markers for Future Highways—Edward Dagner, Manager, Fageol Motors Sales Co.

Philadelphia—No Meeting

Pittsburgh—Jan. 7

Fort Pitt Hotel; Dinner 6:30 P.M.
Valves and Valve Guides—A. T. Colwell, Chief Engineer, Thompson Products Co.
The Story of a Gasoline Motor—Motion Picture

The other papers scheduled for presentation at the Annual Meeting are all to be presented by men who can speak interestingly and authoritatively on their respective topics.

Detroit Section Cooperation

R. N. Janeway, the Detroit Section Vice-Chairman in charge of student activities, has arranged for the Student Session on Monday evening a program that will appeal to members no less than to the students for whom it was specially planned. H. L. Horning, of the Waukesha Motor Co., and T. O. Richards, of the General Motors Research Laboratories, will be the speakers. As an accompaniment to his talk, Mr. Horning will demonstrate a Co-operative-Fuel-Research engine, and Mr. Richards' contribution to the program will be a demonstration of up-to-date instruments used in automotive research.

Alex Taub, Chairman of the Detroit Section, promises that the Dinner at the Book-Cadillac on the evening of Thursday, Jan. 28, when the Detroit Section will act as host to the membership, will be fully up to the standard of similar affairs arranged by the Section, and this assurance is enough to evoke anticipation of a pleasurable evening. All who attend will find special enjoyment in listening to Maurice Holland, Director of the Division of Engineering and Industrial Research, National Research Council, whose talk on Teamwork in Research will be one of the high spots of the week.

Tickets for the Dinner should be obtained in advance from the Detroit Section office, 2-136 General Motors Building, Detroit. The price is $2.50 each, and tickets will not be subject to cancellation or refund after noon on Wednesday, Jan. 27.

Inspection Trips

An invitation has been extended by Pierre Schon, on behalf of General Motors, for those attending the Annual Meeting to visit the General Motors Proving Ground and the plant of the General Motors Truck Co. Members desiring to accept this invitation, or any similar invitation that may be extended, should register for the trip at the S.A.E. Registration Desk. No time during the Annual Meeting will be set aside for inspection visits, but members may make such trips on Saturday, Jan. 30, the day after the meeting adjourns.

Greetings to S. A. E. Members

From President Bendix

Fellow Members of the Society:

IN estimating the accomplishments of our Society, I am impressed by the substantial progress that has resulted from the generous cooperation of the officers, committeemen and other members who have functioned with distinguished success during my administration. I wish that it were possible for me to express personally my gratification and appreciation to all concerned.

To me, the S. A. E. stands for achievement—the sort of achievement in which the best practices of good business and good engineering are combined. Established upon these principles and with a sound reason for being, our Society has grown to be the most successful and vigorous organization of its type that I know. Its high standing, recognized the world over, is founded upon worthwhile attainments of broad scope and far reaching effect. The Society has grown and prospered largely because of its practical service to individual members, the industries which they represent and the world at large.

Financially, our Society is in splendid condition, thanks to the conservatively progressive policies of the officers who have administered our fiscal affairs.

I can see great possibilities for the Society's future and I shall enjoy a continuance of my active interest in its affairs. It is my hope that every S. A. E. member will bring the benefits of individual membership very forcefully to the attention of other qualified engineers who are in a position to enjoy the advantages of our organization. I intend to participate in this effort to the greatest possible extent.

With warm greetings and best wishes for the New Year, I am,

Very cordially yours,

Vincent Bendix

President.

Council Authorizes Free "Transactions"

IN COMPLIANCE with many requests, the Society's Council, meeting in New York City on Dec. 3, voted to provide copies of S.A.E. TRANSACTIONS to members in good standing who request them. It is planned to issue the 1930 and 1931 TRANSACTIONS in a single volume to be mailed early in the new year.

Among other important items discussed by the Council, the Society's cooperation with the Quartermaster Corps of the United States Army, through the medium of our Military Motor Transport Advisory Committee, was considered at length. It seems that the Quartermaster Corps has formulated extensive plans for motorized equipment for Army needs, and the advice of automotive experts of the Society has been sought. The Council voted to reorganize the Military Motor Transport Advisory Committee in order to provide a diversified personnel that can adequately review the plans that have been submitted by the Quartermaster Corps. The new Committee is instructed by the Council to study these plans and to report back to the Council regarding the feasibility of making the major parts and units of the proposed vehicles interchangeable among the various groups, as determined by dimensional standardization of these units and parts.

Organized New-Member Activities

Attention was called to the fact that the Society's membership activities could properly be amplified by organized effort among the Sections and on the part of individual members. Definite steps were authorized to bring the advantages of Society membership to the attention of a greater number of persons who are qualified to become S.A.E. members.

Approval was granted of a survey among the transportation members of the Society to ascertain the attitude of these members concerning practicable specifications of motor-vehicle codes for vehicle regulation.

In the interests of economy the Council approved of printing the 1932 ROSTER with suitable abbreviations and with the geographical index eliminated.

Financial Condition Excellent

A report from auditors of the Society's books was presented and approved. This report brought out the excellent financial standing of the Society.

A report from the Grading Committee was accepted and 27 applications for individual membership were approved. Grade transfers and reapprovals were passed as recommended by the Committee. It was the sense of the Council that special attention should be devoted to delinquent members and that consideration should be given to unusual cases.

It was reported that the American Petroleum Institute has authorized an appropriation of $4,000 for the continuance of the cooperative fuel-research in which the National Automobile Chamber of Commerce, the Bureau of Standards and the Society have cooperated with the American Petroleum Institute.

Appointments Made

Benjamin Liebowitz was appointed to serve as a representative of the Society on the Sectional Committee on Preferred Numbers of the American Standards Association. T. P. Wright was appointed to serve on the Wright Brothers Medal Board of Award for three years and Arthur Nutt was appointed to serve for a like period as a member of the Board of Award of the Manly Memorial Medal. David Beecroft was appointed as the Society's representative on the General Conference Committee of the National Safety Council that is planning the Third Annual Greater New York Safety Conference.

The Council voted its approval of the Society's participation as a joint sponsor in the standardization of finishes on machined surfaces, a project of the American Standards Association.

Approval was granted of a course on research and training of engineers in connection with automotive engineering as planned by Columbia University.

It was understood that the next meeting of the Council would be held on Jan. 14, the day of the Annual Dinner.

Aeronautic Dinner at Miami, Jan. 6

TAKING its place as a regular feature of the All-American Air Races held in Miami annually, an Aeronautic Dinner will again be sponsored by the Society in cooperation with the Aeronautical Chamber of Commerce and All-American Air Race Association. It will be held on the night of Jan. 6 at the Hotel Columbus, Miami, and will mark the close of the Airport Conference of the Aeronautical Chamber of Commerce, which will be held at the same hotel on Jan. 4, 5 and 6, and will provide an opening event for the air races, to be run Jan. 7 to 9, inclusive.

The Hon. Clarence M. Young, Assistant Secretary of Commerce for Aeronautics, as toastmaster, will introduce the principal speaker of the evening, Juan T. Trippe, president of the Pan American Airways. It is anticipated that Mayor Gautier will extend the welcome of the city to those who have attended the Airport Conference and those who arrive for the air races, and introductions will be made of other city and State officials, distinguished guests and fliers.

The All-American Air Races have taken their place among the major National aeronautic events each year, and the Aeronautic Dinner of the Society brings to the members and others interested in this affiair an opportunity to hear this year one of the outstanding men in the field of air-passenger transportation.

The air races are sanctioned by the National Aeronautic Association, which assures the proper distribution of prizes, the accurate timing and the conduct of any record-making attempts.

Annual Meeting Program

Book-Cadillac, Detroit — Jan. 25 to 29

Monday, Jan. 25

STANDARDS SESSION—10:00 A.M.

Reports of Divisions of Standards Committee to be presented and acted upon

FRONT-WHEEL-ALIGNMENT SESSION—2:00 P.M.

Geometry of the Front End—Speaker to be announced later

Front-End Engineering in Relation to the Service-Field Situation—C. P. Grimes, Grimes Brake Engineering Service

Analysis of the Work and Conclusions of the Front-Wheel-Alignment Research Subcommittee—Prof. J. M. Nickelsen, University of Michigan

BUSINESS SESSION—8:00 P.M.

Committee Reports

Standards Committee Report

Nomination and Election of Members-at-Large of Annual Nominating Committee

Announcement of Election of Officers for 1932

STUDENT SESSION—8:15 P.M.

Theory of Internal-Combustion Engines and Fuels—H. L. Horning, Waukesha Motor Co.

Research Instruments—Demonstration by T. O. Richards, General Motors Corp. Research Laboratories

Tuesday, Jan. 26

BEARINGS SESSION—10:00 A.M.

A Possible Criterion for Bearing-Temperature Stresses—D. P. Barnard, Standard Oil Co. (Indiana)

The Manufacturer's Viewpoint on Engine Bearings—D. E. Anderson, Bohn Aluminum & Brass Corp.

The Car Designer's Viewpoint on Engine Bearings—Alex Taub, Chevrolet Motor Co.

BODY SESSION—2:00 P.M.

Noise and Heat Control in the Automobile Body—C. L. Humphrey, Chrysler Corp.

Safety Factors in Automobile Body Design—Maxwell Halsey, National Bureau of Casualty & Surety Underwriters

CHASSIS SESSION—8:00 P.M.

Streamlining and Rear Engine-Mounting—Sir Dennistoun Burney, London, England

Riding-Qualities Research—Dr. F. A. Moss, George Washington University

A New Type of Engine Mounting—N. F. Hadley, R. K. Lee and R. N. Janeway, Chrysler Corp.

Wednesday, Jan. 27

TRANSPORTATION AND MAINTENANCE SESSION—10:00 A.M.

When To Re-Use and When To Junk a Used Part—Joseph Geschelin, *Automotive Industries*

MOTORCOACH AND MOTOR-TRUCK SESSION—2:00 P.M.

Powerplants and Their Relation to the Military Motor Transport of the Army—Col. E. S. Stayer, U.S.A., Quartermaster Corps Motor Transport School

The Super-Range V-12 Engine for Modern Transportation—Hubert Walker, American LaFrance & Foamite Corp.

AIRCRAFT SESSION—8:00 P.M.

Speeding Up the Army in the Air—Brig.-Gen. H. C. Pratt, Chief of Materiel Division, Army Air Corps

Thursday, Jan. 28

DIESEL SESSION—10:00 A.M.

Compression-Ignition Characteristics of Injection-Engine Fuels—A. W. Pope and J. A. Murdock, Waukesha Motor Co.

Air Capacity and Speed of Diesel Engines as a Basis for Appraising Their Automotive Characteristics—Julius Kuttner, New York City

PRODUCTION SESSION—2:00 P.M.

Responsibility of Manufacturing Management for the Present Depression—Gordon Lefebvre, Consulting Engineeer, Detroit

DINNER—6:30 P.M.

(The Detroit Section will act as host to the National Society)

Teamwork in Research—Maurice Holland, National Research Council

Friday, Jan. 29

RESEARCH SESSION—10:00 A.M.

Fuel-System Design and Vapor Lock—Dr. O. C. Bridgemen, Bureau of Standards

The Problem of Gum in Gasoline—Miss E. W. Aldrich, Bureau of Standards

The Fundamentals of Automotive Lubrication—Dr. H. C. Dickinson and Dr. O. C. Bridgemen, Bureau of Standards

AFTERNOON

Committee Meetings

Chronicle and Comment

John N. Willys To Speak WIDELY KNOWN for his ability to inspire an audience, the Hon. John N. Willys will be able to draw upon broad experience and perspective as he speaks to his fellow members about The Automobile Industry—Past, Present and Future at the Society's Annual Dinner in New York City on the evening of Jan. 14. An exceptional event with a few surprises is assured.

Sir Dennistoun Burney at Annual Meeting AMONG NUMEROUS features of extraordinary interest, an address on streamlined cars by Sir Dennistoun Burney will contribute to the success of the Annual Meeting. Sir Dennistoun, who will journey from England to attend the meeting, is expected to bring one or more of his cars with him.

A complete program of the Annual Meeting will be found on p. 23 of this issue of THE JOURNAL.

Get Your Man! NOT AS ominous as it sounds, the slogan "Get Your Man!" will become significant to Society members who attend the Annual Meeting. Watch for the February JOURNAL and special announcements!

The S.A.E. in Miami THE COOPERATIVE work of the Society with the Aeronautical Chamber of Commerce of America will extend to the Far South in the form of a joint Aeronautic Dinner to be held in Miami on Jan. 6 during the All-American Air Races. For the last three years the S.A.E. dinner has been a feature of the races in Miami. The dinner this year will serve as a fitting close to the Airport Conference of the Aeronautical Chamber and an enthusiastic opening for the Air Races which start the next day. Details of the dinner will be found elsewhere in this issue of THE JOURNAL.

What Is New in Engineering? IN THIS issue of THE JOURNAL, Austin M. Wolf provides a very timely review of many new engineering features that are incorporated in the cars to be seen at the shows. "During the last year," Mr. Wolf states, "the engineer has been called upon to help the industry, and it is very clear that he has responded most generously and achieved most effectively."

Free "Transactions" AS AUTHORIZED by the Council, S.A.E. TRANSACTIONS are to be provided free to members in good standing who ask for them. Written requests must be filed at headquarters by Jan. 15, 1932. A single volume, to be mailed early in the new year, will constitute the 1930 and 1931 edition.

Big Jobs Open in Engineering Leadership ACCORDING TO Walter T. Fishleigh, who recently delivered an inspiring address to the members of our Philadelphia Section, "big jobs are open in engineering leadership." Members of the Society will fill some of these jobs!

In this connection, attention is again called to the fact that the S.A.E. Employment Service is available free of charge to employer and employe. Contact can be established directly with the New York City office or through any officer of a local Section.

Rippingille Reviews the S.A.E. Journal AN INTERESTING regular feature of the Detroit Section's *Supercharger* is the "Current Journal Review," prepared for each issue by E. V. Rippingille, Vice-Chairman of the Section's Passenger-Car Activity. Another fine example of Section cooperation in the Society's national activities!

Chairman Alex Taub and his associates are establishing a high record of performance for the Section.

Well Done! DURING JANUARY, many changes will take place in the ranks of Society officers and committeemen. It is difficult to voice adequately the appreciation that is felt by the membership for the devotion that has been shown to the Society by those who retire. Many energetic men have spent hours of labor to effect progress in S.A.E. affairs and the results have been highly satisfactory. In this issue, our esteemed President expresses very warmly his recognition of the intelligent efforts of officers, committeemen and many other members who have been so largely responsible for the Society's welfare.

Certainly, President Bendix himself merits the gratitude of every member for his wise direction and untiring work for the S.A.E.

Reports to Standards Committee THE REPORTS of ten Divisions of the Standards Committee, including the work that has been completed by these Divisions since the Summer Meeting last June, are published as Section 3 of this issue of THE JOURNAL. These reports will be presented at the meeting of the Standards Committee on Monday morning, Jan. 25, at the Annual Meeting and are included with this issue of THE JOURNAL so that all members of the Standards Committee and Society can become familiar with them before they are presented for approval and adoption by the Society, and publication in the 1932 edition of the S.A.E. HANDBOOK.

American Institute of Physics THE AMERICAN Institute of Physics, an agency of cooperation in the interest of physics, has just been established by the American Physical Society, the Optical Society of America, the Acoustical Society of America and the Society of Rheology. This large group has felt the need, first, for unification of effort, and, second, for the existence of an agency which would perfect details of organization and cooperative publication of physics journals and assist the newspapers to disseminate accurate news of important developments and applications of physics. The Institute will serve the four societies mentioned and, through them, physics in general, in matters of common interest.

The new organization is supported by the Chemical Foundation. It is directed by Henry A. Barton.

THE NEW BUICK

Automobile Engineering Progress

By AUSTIN M. WOLF[1]

THE NEW GRAHAM

GENERAL DESIGN and detail mechanical developments that have been made in the last year and incorporated in automobile, truck and motorcoach models for 1932 are reviewed by the author, who also points out noticeable trends in a number of directions. He deals in order with the cars as a whole and with each major component, from the powerplant to the tires and body, as found in many leading makes.

Decision of the industry not to announce the details of new models until the end of the year, at or immediately before the opening of the New York Automobile Show in January, interfered with the presentation at this time of a complete picture of all the improvements made in American motor-vehicles, but enough information is believed to be given to show the more important developments and the ways in which the automotive engineers have responded to the desire of the times for greater refinement and efficiency in automobiles.

The improvements are reflected in better appearance; greater comfort; reduction of air resistance, noise and weight; insulation against heat from the engine; easier control; improved visibility; longer service life of some parts; avoidance of vapor lock; enhanced safety; increased operating economy; and simplified servicing in some cases.

NUMEROUS developments have taken place during the last year covering practically every unit in the automobile. Of particular prominence are the following: 12-cylinder engines, "floating power," copper-cooled valves, inserted exhaust-valve seats, reduction of fan noise, vacuum spark-control, automatic clutch-operation, placing of free-wheeling unit back of the transmission and combining it with dash control, frame front-end bracing and the "ride regulator."

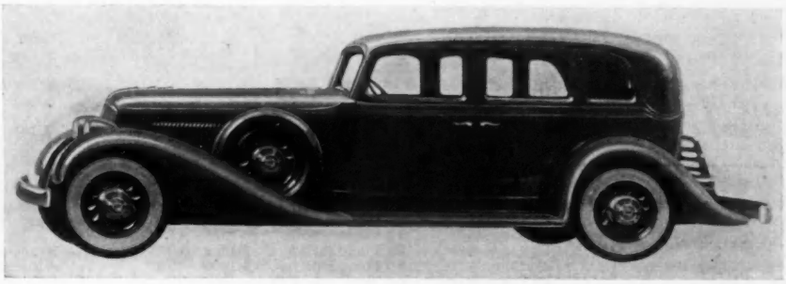
Powerplants

The Pierce-Arrow and Lincoln companies have developed 12-cylinder engines; and the indications are that many men in the high-price-car field see no necessity of going to the extreme of 16-cylinder engines, which are still being used in the Cadillac and Marmon. The Lincoln has a 65-deg. angle between the two banks of cylinders to avoid evenly spaced explosions. This seems a conservatively small deviation from the 60-deg. angle which gives even spacing, particularly when compared with the new Pierce-Arrow, having 80 deg., and the American-LaFrance engine, which has a 30-deg. angle in the V. The cylinders in the last are all cast in one block and, while their offset is only 1½ in. to take care of the side-by-side rods, the general layout recalls the Lancia design. Two cylinder-heads are used, with a centrally located overhead camshaft.

Compression ratios, on the whole, remain at conservative values but in a few instances have been increased, as in the Oldsmobile Eight, which has a 5.9:1 ratio, and the Hudson and Oldsmobile Sixes with 5.8:1. The Cadillac and the Buick companies furnish, as standard, a high-compression head which is used with one of two gaskets of different thicknesses. To obtain low compression, a thick gasket having a steel liner inside a copper-asbestos covering is used. When using the thinner or conventional-type gasket, the output of the large Buick engine is increased by 9 hp. Cooler spark-plugs are supplied with the high compression ratio. An aluminum head is used in the new Graham.

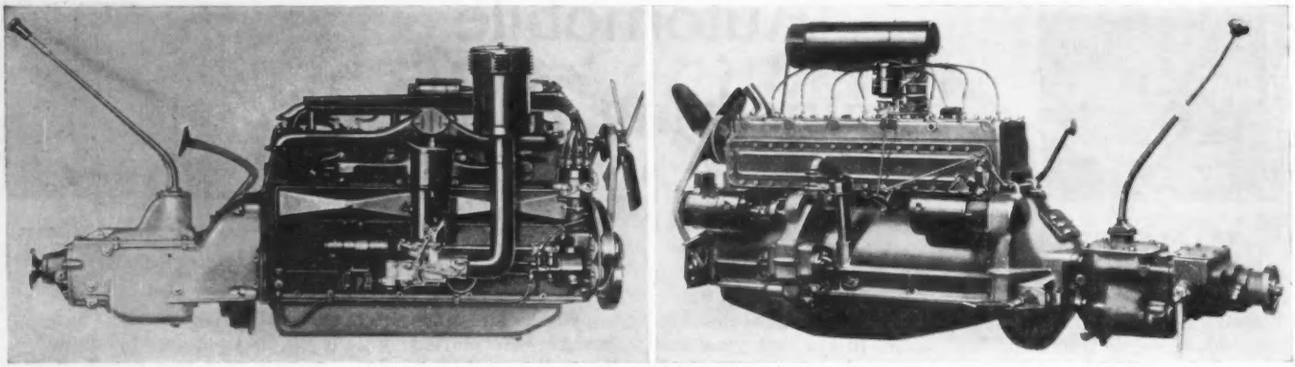
In heavy-duty engines there is a trend to follow the practice already started in some passenger-car units of having the stroke only slightly greater than the bore. Such design permits the use of ample length for all seven main bearings. The process of stiffening the crankcase and cylinder block continues. The use of nickel and chromium in cylinder iron is practically universal. Molybdenum-chromium electric-furnace cast iron is employed in the Hercules engine. While the use of a case-hardened wet cylinder-sleeve was introduced in the Marmon 16, no further gains in this direction have been made other than that the American-LaFrance has a dry nickel-iron sleeve. Owing to the improved structure made possible by centrifugal casting, the use of liners no doubt will increase.

The copper-cooled valve produced by the Thompson Products Co. provides for the rapid flow of heat away from the head. Copper is forged symmetrically into the valve stem and head and is forced well out toward the seat. Because of the greater amount of heat conducted to the stem, it is important to make provision for conducting heat away from the guides. Some Nash models have a graphite-loaded bushing for



THE GRAHAM BLUE STREAK

[1] M.S.A.E.—Consulting automotive engineer, New York City.



POWERPLANTS OF THE NEW HUDSON AND OLDSMOBILE

Note Elimination of Conventional Ball-Housing. The Hudson Transmission Case (Left) Contains the Free-Wheeling Unit, Instead of Its Being Attached Outside

the stem guide. A trend toward increasing the stem diameter is noticed. The Reo has a 30-deg. inlet seat, and the same angle has been adopted for both valves on some of the Continental and Hercules heavy-duty engines.

The inserted exhaust-valve seat is being used in heavy-duty engines to get greater life from the cylinder block and to obtain in the neighborhood of 50,000 miles of service without the need of regrinding or adjusting the valves. The seat usually consists of an alloy of tungsten, silicon, chromium or cobalt. Mack engineers have developed a ring which is held in place by two headed screws. Dodge Bros. uses an alloy of tungsten, chromium and vanadium, which is turned 0.004 in. oversize and pressed into place by a machine that also turns over the block metal around the edge of the insert. White engines have a machine-steel ring which is threaded into the block and locked by two screws. The seat material is Stellite, which is bonded to the ring. This is first rough-ground and then finish-ground when in place in the block.

To obtain increased power, the rocker-arm ratio in the Chevrolet has been increased to provide a lift of 0.309 in. instead of the former 0.277 in. with the former cam lift of 0.212 in. The inlet valve is opened 8 deg. earlier. The rocker-arm of the American-LaFrance engine is split horizontally at the valve end. The lower part is curved where it makes contact against the hardened valve-stem, and a set-screw forces the lower portion toward the valve so that the set-screw itself takes no wear.

Piston and Connecting-Rod

The practice of tin-plating the cast-iron pistons for rapid breaking-in, introduced by General Motors last year, is now used in the Rockne and Studebaker Sixes and the Dictator Eight. The slot in the Packard aluminum piston has been moved from the thrust side to the opposite side to reduce the chance of piston slap due to cocking. Hudson and Essex now have silicon-aluminum-alloy pistons, cam-ground and fitted to 0.0005-in. limits. The Hercules has an elliptical-head split-skirt aluminum piston which, in one of the large models, is perfectly round at the bottom of the skirt and tapers up to the bottom of the rings. The lower ring of the American-LaFrance aluminum piston is positioned circumferentially so as to check slap. The ring groove is only 0.005 in. deeper than the ring thickness, and the oil trapped behind the ring acts as a cushion. Six rings are used in the A. C. F. aluminum piston; five are above the pin, of which the top one is of the regular compression type

ENGINE DATA

Car Model	Compression Ratio	Inlet Valve Opens	Inlet Valve Closes	Exhaust Valve Opens	Exhaust Valve Closes	Piston
Buick 80, 90	4.80 :1 (4.40 :1)	4 Deg. 30 Min. BTC	54 Deg. ABC	58 Deg. BBC	30 Deg. ATC	Cast Iron
Buick 60	5.03 :1 (4.63 :1)	4 Deg. 30 Min. BTC	54 Deg. ABC	58 Deg. BBC	30 Deg. ATC	Cast Iron
Buick 50	5.09 :1 (4.65 :1)	4 Deg. 30 Min. BTC	54 Deg. ABC	58 Deg. BBC	30 Deg. ATC	Cast Iron
Cadillac 16	5.36 :1 (5.00 :1)	TDC	44 Deg. ABC	39 Deg. BBC	5 Deg. ATC	Molybdenum Cast Iron, Tin-Plated
Cadillac 12	5.30 :1 (5.08 :1)	TDC	44 Deg. ABC	39 Deg. BBC	5 Deg. ATC	Molybdenum Cast Iron, Tin-Plated
Cadillac 8 and La Salle	5.38 :1 (5.70 :1)	6 Deg. BTC	42 Deg. ABC	38 Deg. BBC	2 Deg. ATC	Molybdenum Cast Iron, Tin-Plated
Chevrolet	5.20 :1	4 Deg. BTC	34 Deg. ABC	.....	.....	Cast Iron
Essex	5.50 :1	10 Deg. 40 Min. BTC	60 Deg. ABC	50 Deg. BBC	18 Deg. 44 Min. ATC	Silicon-Aluminum
Franklin	5.10 :1	15 Deg. ATC	70 Deg. ABC	70 Deg. BBC	10 Deg. ATC	Aluminum, Invar Strut
Hudson	5.80 :1	10 Deg. 40 Min. BTC	60 Deg. ABC	50 Deg. BBC	18 Deg. 44 Min. ATC	Silicon-Aluminum
Hupmobile, B	5.00 :1 (5.75 :1)	4 Deg. ATC	51 Deg. ABC	47 Deg. BBC	ATC	Aluminum, Invar Strut
Hupmobile, F	5.40 :1 (6.00 :1)	ATC	40 Deg. ABC	40 Deg. BBC	ATC	Aluminum, Rayday Split-Skirt
Hupmobile, I	5.475 :1	1 Deg. ATC	51 Deg. ABC	47 Deg. BBC	3 Deg. ATC	Aluminum, Rayday Split-Skirt
Lincoln 12	5.25 :1	21 Deg. BTC	47 Deg. ABC	57 Deg. BBC	11 Deg. ATC	Aluminum, Split Skirt
Marmon 16	6.00 :1	6 Deg. BTC	40 Deg. ABC	40 Deg. BBC	6 Deg. ATC	Aluminum, Rayday Split-Skirt
Marmon 8, 125	5.50 :1	TDC	50 Deg. ABC	50 Deg. BBC	10 Deg. ATC	Aluminum, Split Skirt
Oldsmobile 8	5.90 :1	TDC	50 Deg. ABC	40 Deg. BBC	10 Deg. ATC	Cast Iron
Oldsmobile 6	5.80 :1	TDC	50 Deg. ABC	40 Deg. BBC	10 Deg. ATC	Cast Iron
Reo 6-25	5.30 :1	TDC	50 Deg. ABC	48 Deg. BBC	2 Deg. ATC	Silicon-Aluminum
Reo 8-21, 25	5.37 :1	5 Deg. BTC	40 Deg. ABC	50 Deg. BBC	5 Deg. ATC	Aluminum, Invar Strut
Reo N-31, 35	5.30 :1	TDC	50 Deg. ABC	48 Deg. BBC	2 Deg. ATC	Silicon-Aluminum
Rockne 65		5 Deg. BTC	40 Deg. ABC	40 Deg. BBC	5 Deg. ATC	Cast Iron, Tin-Plated

and the next four are combined compression and oil-control rings. The piston-head thickness in the Plymouth has been increased to reduce detonating tendency. Molybdenum cast-iron pistons are used in the Cadillac 12 and 16-cylinder engines.

Oil-control rings with the wide center-relief are very popular. The Perfect Circle Co. continues with its endless relief, for which is claimed uniform distribution of oil and maximum drain capacity. Other makers believe that a greater flushing of oil toward and through the slots is obtained by the use of narrow vertical bridges which interrupt the continuity of the relief. The American Hammered Piston Ring Co. provides two such bridges spaced 90 deg. from the joint, while the Piston Ring Co. places bridges between all of the eight slots.

The aluminum-alloy connecting-rod has made no further progress. Floating piston-pins and rifle-drilled connecting-rods have slightly increased. Connecting-rod failures sometimes result from big-end distortion, allowing the babbitt to deflect and crack. The hollow-milled integral cap-studs inaugurated by Ford have been adopted in the Hercules to prevent such failure.

Crankshaft and Lubrication

Crankshafts are now being counterweighted in cars in the low-price class, including Chevrolet and Rockne. The former is fitted with a harmonic damper and the latter has a Lanchester vibration damper. On some of its models the Nash Motors Co. is using the bonded-rubber type of damper. Heat-treated chromium-molybdenum steel is employed by the White Co. in the crankshaft of its large motorcoach engines. Steel-backed main bearings have been adopted for the Studebaker and Rockne. Chevrolet main bearings have the same outside diameter as formerly, but the shell thickness is reduced to provide for larger journals. The bond of the bearing lining is now at the neutral axis of the whole bearing unit. There is also pressure feed to the main and camshaft bearings and valve stems.

An air-cleaner has been added to the crankcase breather pipe in the Packard. In the Buick the breather has been moved to the center of the crankcase to reduce noise.

Oil-temperature regulation is increasing. On the Nash Six the oil-cooler is mounted on the side of the water-jacket cover-plate. In it the oil passes through venturi tubes which are surrounded by water. A radiator-type oil-cooler is mounted between the radiator and the water-pump on the Model 870. The core of the Buick cooler is tilted to insure complete draining. In the Oldsmobile, the cooler unit is below the pump inlet and the core is placed vertically. Packard engineers have dropped the lubricating manifold interconnected with the choke and provided adequate cylinder-wall lubrication by moving the oil hole in the connecting-rod to the trailing side. Pierce-Arrow engineers have made a similar change in the hole. In the Willys-Knight, oil enters the main bearings at the side and is distributed through an oil groove extending through the lower half. It is carried around the upper half by its adherence to the journal. On a large Hercules engine, a five-gear oil-pump is used. Two gears form the pressure pump and the other three are used to scavenge both ends of the sump so that the engine will operate at a 30-deg. tilt. Dip troughs for the rods provide splash lubrication in starting cold. Oil is supplied from the pressure-regulator overflow, and the supply stops when the oil is warmed up. Twin filter units are used on large engines. There is an increase in the use of metal filters, particularly the circular-wound-wire type with narrow spaces between the coils made by upsetting the wire at intervals. On the Cadillac 12 and 16, the filter is automatically cleaned with each application of the starter pedal.

Engine Cooling

One of the noteworthy developments of the year is the reduction of the apparent fan noise by blending it with other powerplant noises at the speeds and under the operating conditions at which it has been bothersome. This has been done by changing the angular spacing of the blades. The problem has been attacked in the new Chevrolet four-blade fan by making the two pairs of opposite blades of different width, resulting in vibrations of different frequencies which tend to cancel each other.

Cooling capacity in the Buick has been increased by the adoption of thicker radiator cores and an increase in fan capacity. While cores are more efficient today, sustained high speeds and free-wheeling call for greater dissipating ability. The Hudson company has designed its cooling system on the basis of a sustained speed of 70 m.p.h. without boiling at 100-deg. atmospheric temperature. While some makers have increased the water capacity around the cylinders, there is also the trend, as exemplified in the Buda Hivelo, toward carrying a comparatively small volume of water in the cylinder jackets so as to provide for rapid warming up, the water being circulated at a high rate. Water is circulated at a rate of 1 gal. per min. per hp. in the larger Continental engines. In the White motorcoach engine, the water-pump bearings are lubricated by the oil-pump. The Hercules engine has a pump with two impellers, each discharging into a block of three cylinders. For neat appearance, the Lincoln has an easily removable shield over the water-pump, driveshaft and coupling.

FAN DATA FROM AUTOMOTIVE FAN & BEARING CO.

Model	Blade Spacing (4-Blade Fans), Deg.
Buick, 8-80 and 8-90	70 and 110
Buick, 8-60	70 and 110
Buick, 8-50	73 and 107
Chrysler 6	60 and 120
Chrysler 8	50 and 130
Chrysler Imperial	65 and 115
Continental Engines, 600	70 and 110
DeVaux-Hall	76 and 104
Dodge 6	60 and 120
Dodge 8	50 and 130
Durant (Model) 612	70 and 110
Hupmobile I	60 and 120
Hupmobile 6, B	76 and 104
Hupmobile 8, F	76 and 104
Lincoln	42 and 78[a]

[a] Six-blade fan.

The V-front radiator is becoming very popular and has been adopted by some of the most conservative car manufacturers. As a rule the shell and shutters form the V. The false upper tank is now a thing of the past and the shutters are extended to the top contour. A false bottom is displacing the former radiator apron. In the Cadillac 12 and 16, the chromium-plated grille is built in. The Chevrolet grille is an integral part of the radiator. Chromium beads have been placed on the shutters of the Buick, while the Pierce-Arrow company chromium-plates the entire shell, including false bottom and shutters.

The shell of the Graham Blue Streak has a decided tilt, paralleling the slope of the windshield in the side view. It terminates in a forwardly curved V at the

apron. The plane of the core is parallel to that of the fan, the filler being under the hood. The wire bail formerly used on the Packard has been eliminated to "clean up" the filler cap, which is now larger and lower. Some of the Nash models have a pronounced V, with the shell lacquered to match the body color and trimmed off with chromium beading.

The Franklin company has still further reduced the power requirements of its fan blower and developed the temperature control of the engine so that the operating temperature does not vary more than 20 deg. fahr. between different engines.

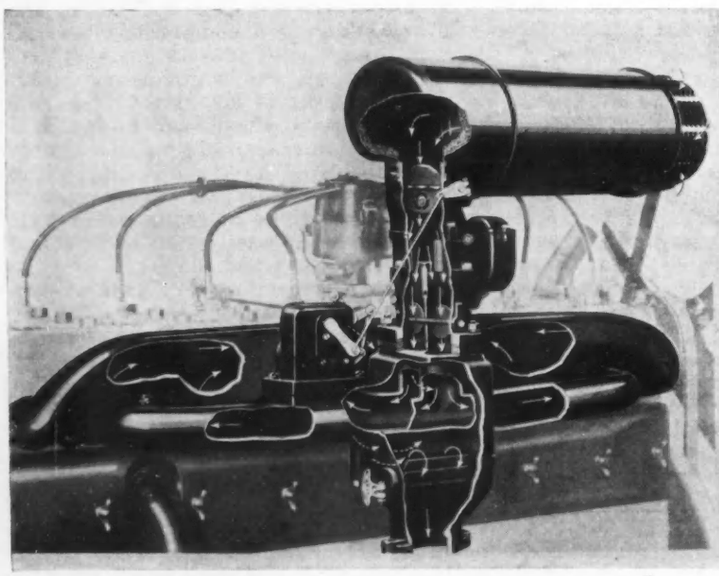
Carburetion, Fuel and Exhaust Systems

The downdraft carbureter is increasing in number. Dual carbureters are used on nearly all of the eights, including the smaller Buick and Lincoln. The combined air-cleaner and intake silencer is also universal. A Burgess silencer is fitted on the Pierce-Arrow, immediately back of the cool-air intake, retained from last year. In the heavy-duty field, the oil-bath type of cleaner is being used where dust is prevalent. The United cleaner is provided with a lead from the exhaust to raise the oil spray into the air screen, resulting in circulation of hot oil.

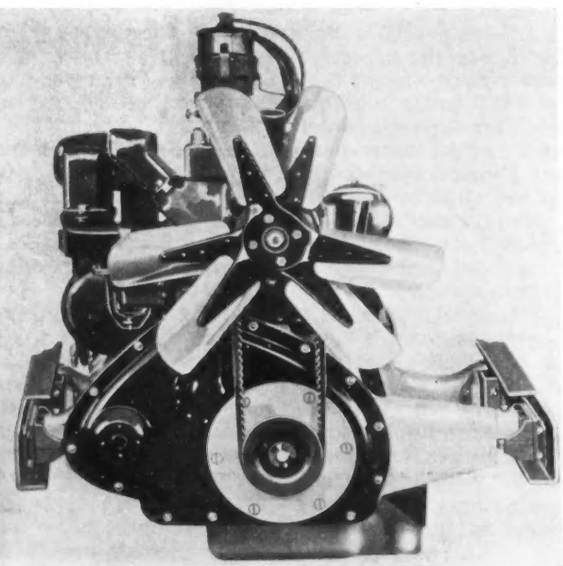
Pierce-Arrow cars retain the hot-air control by means of a thermostat which is responsive to exhaust-manifold heat. The Hudson and Essex have a thermostat controlling the flow of exhaust gas around the inlet riser. The Oldsmobile has an automatic choke based on the same principle. The Sisson automatic choke utilizes, in addition to the above, a solenoid. When the starter is operated, an electric current flows to the solenoid and the magnetic action closes the choke if the engine is cold. On the Chevrolet a split choke predetermines the amount of choking for ordinary conditions. The Chevrolet also has a heat-control valve in the exhaust line, with dash button-control. Nash cars have an engine primer whereby a shot of fuel will be injected by the pump only the first time the accelerator is depressed. Exhaust heating of the inlet manifold has been discarded on the Stutz and replaced by water leaving the jackets. A thick heat-insulating gasket is used between the Oldsmobile downdraft carbureter and the manifold. Exhaust heating of the inlet is retained in this engine by the use of a weighted control valve in conjunction with an adjustable spring resistance.

To provide a cold-air inlet from outside, the Buick has a door-scoop located in the lower front end of the hood, directing the outside air toward the inlet. Thus the temperature of the air entering the carbureter has been lowered 40 to 50 deg. In addition, a shield has been placed over the enlarged intake-silencer to protect it from the exhaust-manifold heat. In the Willys-Knight, the forward portion of the inlet manifold is shielded against cooling drafts to prevent fuel condensation. By a complete redesign of the manifolds, carbureter and exhaust system, the output of the Cadillac Eight has been increased from 96 to 115 hp. at 3000 r.p.m.

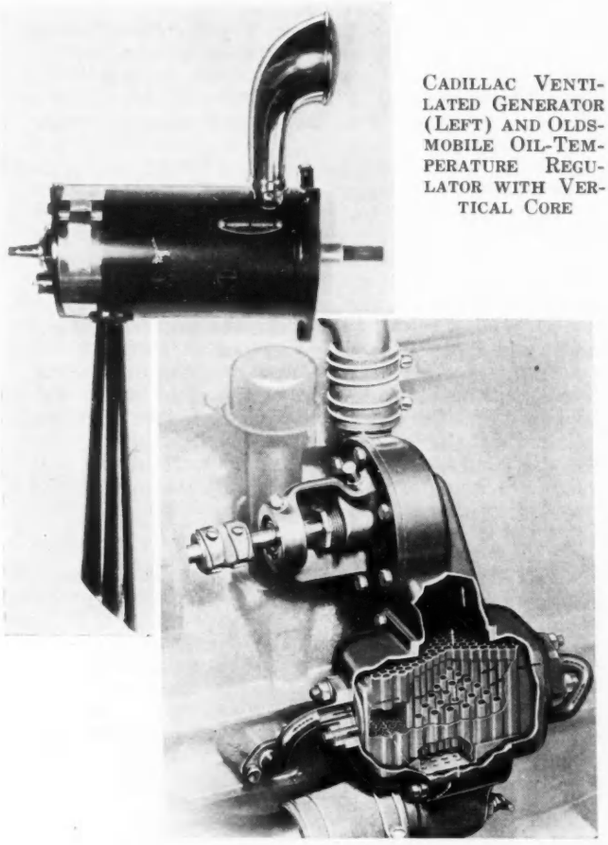
Vapor lock has been discussed extensively during last year, and the new cars are using various means to keep down the temperature within the fuel lines. Buick, Hudson and Pierce-Arrow cars have the fuel line on the outside of the frame on the side opposite the muffler, and where the line is exposed under the hood it is covered with heat-insulating material. However, much remains to be done in removing the fuel-pump from the crankcase, where it is subjected to the engine heat and the hot oil. The Lincoln has it mounted at the forward end of the engine, where it is clear of the crankcase and is actuated from the camshaft, a method introduced by Packard last year. The Hudson and Essex still retain the vacuum tank because of its ability to clear away vapors originating in the line up to the tank. In the Buick carbureter, the jets extend down into the bottom of the fuel well to prevent the picking up of below-surface vapor bubbles, which can pass out of the float chamber through a large vent. Nash and Pierce-Arrow cars have the forward part of the exhaust pipe to the engine pan covered with asbestos to reduce under-hood temperatures. The Burgess muffler is now being used on the Packard, Chrysler, Lincoln, Pierce-Arrow, Studebaker, Stutz, Hudson, Essex and DeVaux. The Hudson and Packard also mount the muffler frame-brackets in rubber. Various effects can be obtained by different sound-absorbing materials in the Burgess muffler, and it is interesting to note that the Pierce-



OLDSMOBILE MANIFOLDS, CARBURETER AND AIR-CLEANER-SILENCER
Note the Automatic Choke Control



PACKARD ENGINE FROM THE FRONT, SHOWING UNEVEN FAN-BLADE SPACING



CADILLAC VENTILATED GENERATOR (LEFT) AND OLDSMOBILE OIL-TEMPERATURE REGULATOR WITH VERTICAL CORE

Arrow tandem muffler has mica lining in the front unit and steel wool in the rear unit. Opposing sound characteristics are obtained also in the Hudson. The Nash muffler is wrapped with asbestos covered with sheet metal. The Lincoln engine now has a front exhaust in which a Y-shaped manifold connects with the two cylinder-block manifolds, swinging over to the left side and having a shield in front in the proximity of the fan belt.

Use of the front outlet from the exhaust manifold is increasing in the heavy-duty engines. In the White motorcoach engine all the exhaust gases are conducted from the left side through a central passage in the head to the right side. The exhaust-manifold extension of this side surrounds the carbureter inlet riser and terminates with the flange for the exhaust pipe. This design is asserted to prevent exhaust-manifold breakage.

Whereas exhaust-gas analysis was formerly a laboratory procedure, the mixture ratios can now be determined in a few moments by means of handy instruments. Variation in temperature of a heated platinum wire acting as one side of a Wheatstone bridge gives a reading of the air-fuel ratio. Such instruments are the Moto-Vita and the Englehard Air-Fuel Ratio Analizer.

Electrical Equipment

Vacuum spark-control has been developed by the Delco-Remy company into four possible methods:

(1) Retardation of the spark by high vacuum above the carbureter, as embodied in the Plymouth and Rockne cars and obtained by tapping into the carbureter on the engine side of the butterfly valve. Idling at a lower speed or a more stable idle is obtained. When the engine attains a speed equivalent to 6 or 7 m.p.h., the spring in the diaphragm chamber advances the distributor to the full manual-advance position. From here on the centrifugal automatic mechanism carries on the advance.

(2) Advance of the spark with light load to obtain greater economy is accomplished by tapping a lead into the carbureter on the carbureter side of the butterfly valve. At closed throttle or idling speed, the vacuum at the diaphragm is very low and the spark is retarded to normal centrifugal spark-advance timing. As the throttle is opened slightly, a high vacuum is applied to the diaphragm and the spark is advanced by vacuum. As the throttle is opened, the spark is related to the vacuum at the diaphragm, and when the throttle is opened wide the spark advance drops back to the centrifugal automatic advance.

(3) For retardation of the spark with low vacuum, the diaphragm unit is mounted on the distributor arm, as embodied in the Studebaker President, and connects with a dash control-arm by means of a spring built into the diaphragm assembly which tends to separate the two arms and move the distributor to retarded position. This occurs between three-quarter and wide-open throttle position when the inlet-manifold vacuum is low. A lead runs from the manifold to the diaphragm chamber. As the throttle is closed, the vacuum becomes greater, overpowers the diaphragm spring and advances the distributor to normal timing.

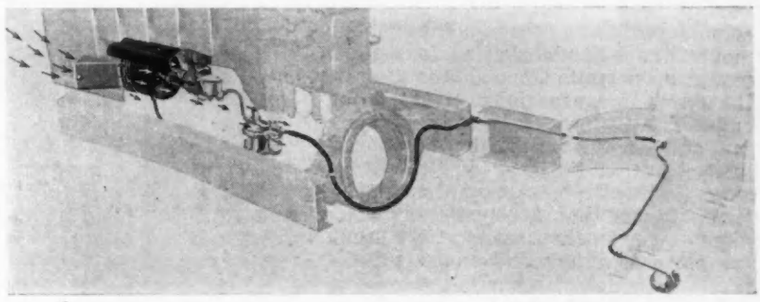
(4) Methods (1) and (2) are combined by means of two leads tapped into the carbureter so that, in conjunction with the conventional centrifugal advance, they form a fully automatic ignition control.

The Packard company has adopted the 14-mm. sparkplug. A radio plug in which a comparatively high resistance is incorporated in the central electrode has been developed by the A. C. Spark Plug Co. Being in series with the spark gap, the oscillatory discharge can be suppressed and interference eliminated.

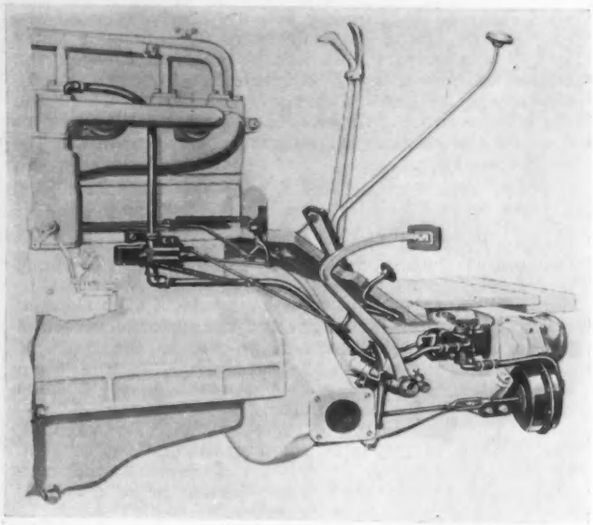
The Lincoln now has the ignition distributor placed at the rear end of the engine. The distributors on the Hudson and Essex are fitted with a graduated scale for timing, as a service aid, indicating advance in inches on the flywheel.

Startix, an automatic starting-switch, is used on a considerable number of cars ranging from the Rockne to the Pierce-Arrow. It starts the engine when the ignition key is turned "on," repeats if the engine does not continue running, and automatically restarts if the engine stalls at any time. Ten-pitch gears on the starting clutch replace the 8-10 pitch formerly used on the Buick. With the same diameter of flywheel and gear centers, the number of teeth in the flywheel has been increased from 125 to 156.

To eliminate the danger of overheating, a ventilated two-pole-type generator is used on the Cadillacs, with



BUICK FUEL-SYSTEM LAYOUT TO OBVIATE VAPOR LOCK
Note the Cold-Air Inlet Scoop below the First Door Ventilator



AUTOMATIC CLUTCH-CONTROL OF THE BUICK

thermostatic and third-brush control. An intake scoop at the top of the generator faces the radiator fan, an outlet extends down through the splash pan and air is sucked from the outlet by the pitot-tube action.

The Oldsmobile has a triangular drive around the crankshaft, fan and generator pulleys, with the water-pump drive through the generator. Generators have been speeded up to compensate for loss of charging when free-wheeling. Generator-output demands are increasing in the heavy-duty field. Whereas trucks were formerly requiring 115 watts, the demand has now reached 150, while motorcoaches call for 1000-watts output.

Location of the battery in a box incorporated in the right front fender, established by the Packard a number of years ago, is now noted throughout the Cadillac line.

Mounting and Miscellaneous

The Plymouth mounting, with an axis through the center of gravity of the powerplant, may give a new lease of life to the four-cylinder engine.

The use of rubber is increasing, and it is interesting to note that rubber is again utilized in the Packard after having been discontinued. The Lincoln now has a three-point rubber mounting. Studebaker's four-point mounting permits some side motion of the crankcase, especially at the front end. The Six has a "softer" mounting and includes a rubber-cushioned torque-arm at the rear of the crankcase. The Pierce-Arrow has large rubber units that are unusually soft. The two suspension points at the front are close together and make practically one point. Similarly, two rubber cups at each of the mountings adjacent to the flywheel-housing and at the rear of the transmission under the free-wheeling unit can be regarded as "points." Considered rotationally about a longitudinal axis, the eight-point Pierce-Arrow mounting is essentially four-point, with the front and rear points in fair alignment. The Chevrolet and Rockne have four-point rubber mountings, the former having one support under the free-wheeling unit.

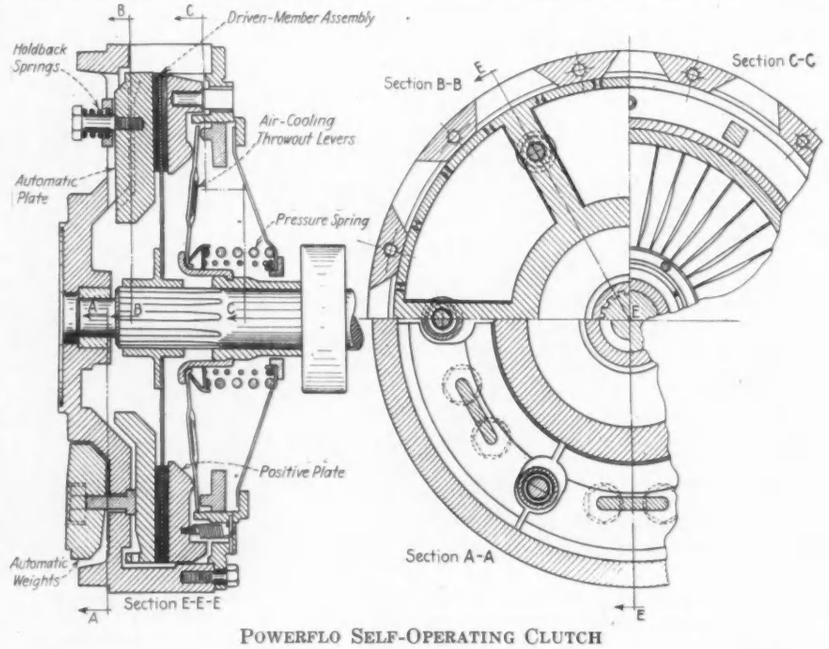
A trend in heavy-duty engines is toward the grouping of all accessories on one side, assuring centralized and maximum accessibility. A vacuum pump for the windshield wiper, as developed by the A. C. Spark Plug Co., is a combination fuel-and-vacuum pump. A diaphragm is subjected on one side to manifold vacuum and has an increased stroke as the vacuum drops, thereby maintaining a constant suction and producing the same number of wipes per minute over the entire range of throttle opening and speed. Tachometer drives are being demanded in motorcoach and truck work. A drive developed by the A. C. Spark Plug Co. consists of a housing fitting into the standard S.A.E. distributor take-off. The distributor fits into the upper part of the housing and the tachometer drive comes off horizontally through a helical hardened-steel gear drive with a 1:1 ratio.

Clutch

Automatic clutch-control is one of the preeminent developments. The Bendix clutch control, originally brought out for adaptation to existing cars, has been further developed by the Buick company by the addition

CLUTCH AND TRANSMISSION DATA

Model	Clutch	Gear Ratios In Second	In Low	In Reverse
Buick, 80, 90	Two-Plate	1.714 :1	2.828 :1	3.535 :1
Buick, 60, 50	Single-Plate	1.737 :1	2.894 :1	3.474 :1
Cadillac, all models	Two-Plate	1.47 :1	2.40 :1	2.49 :1
Chevrolet	Single-Disc, Cushion Mounted	1.77 :1	3.32 :1	4.20 :1
Essex and Hudson	Single Aluminum Plate, Cork Insert, Cushion Driven	1.62 :1	2.44 :1	3.26 :1
Franklin	Disc (Brown-Lipe)	1.646 :1	2.864 :1	3.437 :1
Hupmobile, B, F.	Single-Plate (Borg & Beck)	1.56 :1	2.71 :1	3.255 :1
Hupmobile, I	Plate (Long)	1.559 :1	2.873 :1	3.750 :1
Lincoln 12	Two-Plate	1.78 :1	2.91 :1	3.43 :1
Marmon 16	Plate (Russell)	1.57 :1	3.08 :1	3.85 :1
Oldsmobile	Single-Plate (Borg & Beck)	1.66 :1	2.90 :1	3.67 :1
Reo, 6-25, 8-21, 25	Single-Plate	1.67 :1	3.13 :1	.....
Reo, N-31, 35	Two-Plate	1.38 :1	2.29 :1	.....
Warner Gear Co., T-83		1.604 :1	2.819 :1	3.383 :1
Warner Gear Co., T-81		1.646 :1	2.864 :1	3.437 :1
Warner Gear Co., T-82		1.700 :1	2.833 :1	3.400 :1



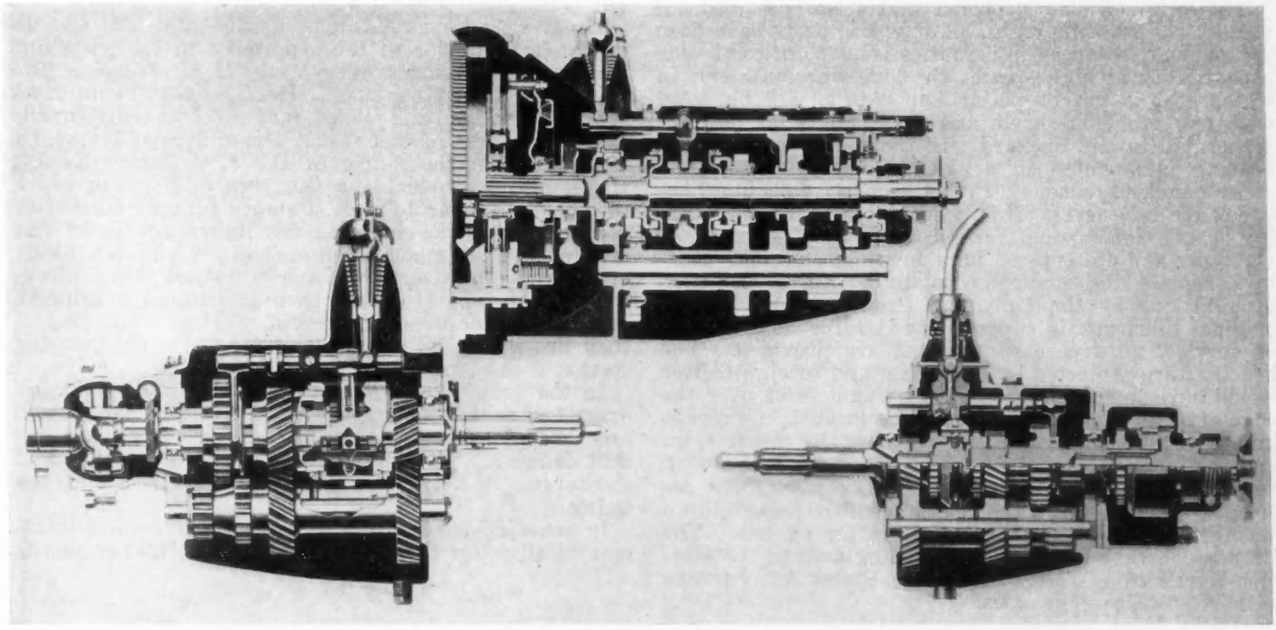
POWERFLO SELF-OPERATING CLUTCH

of a button control-valve and the rate-of-engagement selecting valve which is actuated by the shifting-bars of the transmission. The regular clutch-pedal has been retained and is not affected by the automatic control. The clutch facings have a higher coefficient of friction, to decrease wear and maintain constant smoothness. Increased hold-out of the clutch for coasting has been provided for by the use of larger throw-out and pilot bearings. The Hill vacuum-operated clutch-throw-out is controlled either by a button above the gearshift lever ball or by an accelerator pedal which controls the clutch movement with the pressing down of the heel.

Experience gained with brake-drum materials is now being applied to clutch plates, some of which are made of high-grade cast iron. Double-plate clutches have individual hubs so that wear on all four friction facings is more uniform. A 16-spline clutch-shaft is now used in the Packard in place of a former 10-spline shaft. The clutch throw-out is now of the walking-beam type.

a series of radial ball-locks under spring pressure to release the cone. The Chevrolet has a synchronizing member with "detent" springs. The second-speed gear is at the rear of the case, while the low-speed sliding gear is centrally located and supported on the control sleeve for second speed and high. The Oldsmobile has a similar construction but helical gears are used for the constant-mesh pairs. Helical gears are also used in the Buick, Cadillac, Lincoln, Hudson, Graham, Rockne, Studebaker, Pierce-Arrow and Hupmobile.

In the Buick transmission the synchronizing clutches have been increased in size over last year, and roller bearings have been adopted for the countershaft. The shift lever has been mounted on the clutch housing to give more room in the front compartment. To prevent oil leaks, a boot is placed over the universal ball-housing and oil seals are located at the forward end of the shifting forks, at the backing-light switch and at the front end of the countershaft. In the Plymouth, constant-



TRANSMISSIONS OF THE PACKARD (TOP), BUICK (LEFT) AND GRAHAM (RIGHT)

To exert a more uniform pressure on the friction discs, the Chevrolet now has three pressure levers instead of four. The clutch fork is mounted on a special spherical swivel, which, with the three-lever construction, insures perfect alignment of the release bearing, which is made of carbon-graphite composition. The clutch springs are spaced in three groups of three springs each between the levers. The clutch disc is cushion-mounted at the hub through eight springs. The automatic clutch, with springs that separate the friction surfaces and oppose the centrifugal weights which bring the plates into contact at 400 r.p.m. and establish complete contact at 700 r.p.m., provides a simplified control and easy engagement. This has been adopted by Twin Coach. The flat throw-out levers are bent in mid-section to form a fan vane. Circulation is established, the air being discharged through holes in the periphery of the flywheel.

Transmission

Synchronizing cone clutches have been widely adopted by the industry. The Packard utilizes an oil-dashpot timing mechanism; and the Nash, Pierce-Arrow, Studebaker, Hupmobile, Graham and Rockne are provided with

mesh gears are used for second speed, and second or high is selected by a sliding internal-gear member in which alternate teeth are undercut for easy shifting.

Free-wheeling has taken a decided step in the placing of the unit at the back end of the transmission, where it is effective in all forward speeds and usually is provided with a dash control. The use of synchronizing clutches has made this mounting necessary. Hudson and Essex cars, in which this system was first adopted, with the use of roller ratchets, retain the lever control on the floor-board and are the only ones in which the unit is housed integrally within the transmission case. The coiled rectangular-section driving spring inaugurated by the Auburn company is now to be found also on the Cord and Duesenberg, with lever control on the floor-board. The coil-spring drive is optional on some of the G.M.C. motorcoaches and is built in the largest units ever put into use. They are supposed to have a maximum torque capacity of 16,000 ft-lb. The Chevrolet has a coil-spring drive, locked in or out by a push-pull button on the dash.

In place of the previous roller-ratchet free-wheeling units composed of elements of three different diameters

in a group, the practice is now to use a single roller in each pocket, except in the case of Plymouth. Six rollers are used in the Willys and small Studebaker, and eight in the Pierce-Arrow, Studebaker President and Hupmobile. The cam on which the roller rides has been redesigned to lower the wedge angle, reducing slippage and providing easy engagement. Whether control is by lever or button, its position indicates whether the car is free-wheeling or not. The Studebaker has a "gage" on the instrument board for this purpose. The free-wheeling unit is designed so that shifting into reverse automatically locks out the unit and at the same time compresses a spring. With the return of the main gear-shift lever to neutral, the overrunning clutch is brought back automatically to the free-wheeling position. The Rockne has a lock-out control interconnected with the clutch so that it must be thrown out before engaging or disengaging the free-wheeling drive.

Universal Joint

The whip of long propeller-shafts can possibly unbalance the rotating train, all of whose parts have been scrupulously balanced in manufacture. To prevent such a possibility at high speeds, the long-wheelbase car, in which cost is not of major importance, will be fitted with two propeller-shafts and three joints, as now incorporated in the Packard. In the center support, the bearing is mounted in a casting insulated from the cross-member bracket by rubber securely vulcanized between the two parts. This prevents objectionable bearing or axle noise being transmitted to the frame.

A yoke-and-pin type of joint in which "needle" bearings replace the customary plain bushings has been brought out by the Universal Products Co. As the original lubricant is supposed to last for 50,000 miles of service, no grease connections are provided. The bearings are protected by a packing, and foreign matter would have to travel against centrifugal force over the edge of a cup in which the packing is located. Graphite-impregnated washers are used between the center block and the inner face of the yoke of the Blood Bros. joint, and for close-coupled installations this company has developed a double joint, the center member resembling a spring shackle having a center reinforcing bar. The Rzeppa constant-velocity joint is being used in the Marmon-Herrington, Walter and United States Army trucks with Wisconsin front axles.

Rear Axle

Rear-axle tracks are still being widened, the Packard having a 59-in. track and the Pierce-Arrow and Studebaker President 61½-in. Axles are being stiffened for strength as well as for torque transmission. Buick engineers have stiffened all the rear axles; the differential carriers now have external ribs and the diameter of the torque tubes on the two larger chassis have been increased in diameter. Bronze thrust washers are now placed back of all differential gears to prevent scoring. The pinion-bearing spacers are keyed to the shaft. Pitch of the gears has been changed in the Packard to reduce backlash and thereby obtain greater quietness. Rear-axle shafts in this car are now 10-spline instead of 6. The differential carrier is braced by extending the carrier studs through the carrier and adding a nut on the outside.

To eliminate localized stresses in the axle shafts in torsion due to sudden power application, Timken has reduced the body diameter of the shafts to a dimension slightly less than the root diameter of the splines at the end of the shaft. Each shaft is also provided with a coil of wire snugly fitting the outer end of the shaft in right and left-hand spirals which acts as an oil return. This prevents the warm center-housing lubricant from reducing the wheel-bearing grease to a liquid state. The Timken High-Traction differential provides a variation in the lever-arm of the tooth contact between pinion and side gears, varying between 1.63:1 and 1:1.63 instead of being constant. The increased torque transferred to the side gear connecting to the wheel having greatest traction is supposed to be sufficient to maintain propulsion of the vehicle until traction has again been equalized.

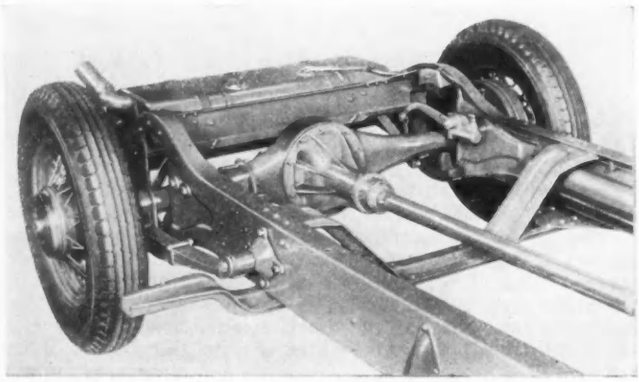
Considerable activity is noted in the six-wheel field, and, where two driven axles are used, an inter-axle differential has been found indispensable. The Federal company is using two bevel-gear axles, the power to the rear axle being obtained from a pinion meshing with the front ring-gear and diametrically opposite its driving pinion. Where a single driving axle is used, Federal locates it at the rear, claiming increased traction for this construction. To clear the propeller-shaft, the forward dead axle has a center yoke offset downward, into which are pressed the tubular ends.

Brakes

Great activity pervades the brake-drum field and indicates a repetition of the experience in the truck and motorcoach field a few years ago. Motor Wheel is producing the Centrifuse drum, which consists of an outer steel ring, flanged and ribbed, into which is centrifugally cast a thickness of cast iron. The ring is subsequently welded within the flange of the steel back. Kelsey-Hayes also is producing a new type of drum in which the back is a separate piece, stamped for maximum stiffness in view of the comparatively light gage used. The braking ring is made of alloy steel (S.A.E. No. 5140) of hot-rolled-mill section which is hooped into a circle, welded, carefully sized and then normalized to improve the grain structure and prevent scoring. The ring is then arc-welded to the back plate. Ribs on the ring section give strength and aid cooling.

In the heavy-duty field, the Gunite Air-Blast brake-drum has radial fins cast on the inner back face which are covered by a thin plate forming a centrifugal fan that draws air through holes near the inner edge and discharges it between the braking surface and the lining.

In general, brake linings have been increased in thickness to allow for the greater wear due to higher speeds and free-wheeling. There is an increase in the use of zinc alloy and lead wire in the manufacture of brake linings. Because of the extremely high pressure at the self-energizing shoe or at the end of the brake-band, hard, full-molded segments have been used considerably. While this has been ideal from the manu-



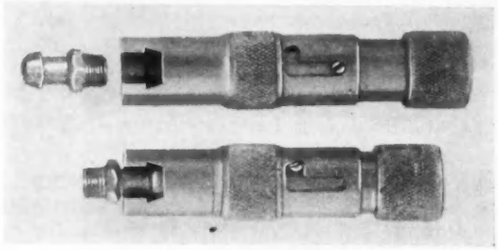
REAR END OF THE GRAHAM CHASSIS, SHOWING REAR AXLE EXTENDING THROUGH OPENINGS IN THE FRAME AND THE CROSS-MEMBER CONSTRUCTION

facturing end, it has complicated servicing and the World Bestos Corp. has developed a semi-rigid molded lining that can be cut to lengths from a roll. American Brakeblocks are now furnished with an alloy grid backplate which gives a greater thickness of usable brake material.

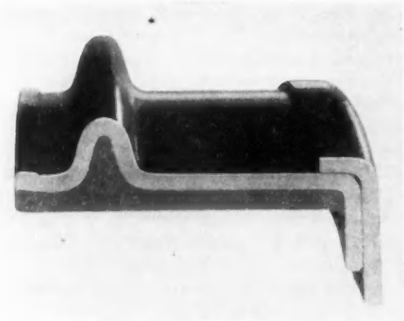
Water-cooled air compressors are now obtainable. The front-end compressor mounting has not made much

TIRE & RIM ASSOCIATION DROP-CENTER STANDARD

Tire Size	Rim Size
4.75	3.00-D
5.00	3.00-D
5.25	3.25-E
5.50	3.25-E
6.00	3.62-F
6.50	3.62-F
7.00	4.00-F
7.50	4.37-F



LOCKITE GREASING-SYSTEM FITTING AND COUPLING



SECTION OF MOTOR WHEEL CENTRIFUSE BRAKE-DRUM

headway, probably because of reluctance to make the change in radiator design that is necessary with this mounting. Hence a greater number of installations have a side mounting on the engine, with the compressor often midway in the accessory layout.

Lincoln has now adopted the booster brake to relieve foot pressure. Packard is mounting the cross-shafts in self-aligning spherical bushings which are automatically lubricated. The Rockne hand-brake operates on all four wheels. Buick now has pressed-steel axle housings on which the brake-flange discs are welded on instead of being riveted castings. The brake rods are fitted with anti-rattle springs at all connections. Stewart-Warner is offering a power unit or servo mechanism which is mounted at the rear of the transmission together with all the brake rigging, including the four-wheel brakes. The shoes are forged from high-carbon-steel rolled sections of special shape, with the cam contact surfaces forged on and hardened.

Front Axle

In keeping with the increased rear-axle track and to permit use of a deeper frame, as in the case of the Packard, the front axle also has been increased in length. The Lincoln tops the list with a track of 60 in., making it the same as the rear-axle track. The Pierce-Arrow comes next, with 59½ in., while all Studebaker models have 59 in.

The tie-rod in the Hudson and Essex is rubber mounted on oilless bushings, eliminating direct metal contact and damping out vibrations on rough roads. In the Chevrolet tie-rod the former round-wire springs have been changed to rectangular section.

Wider-track axles have been brought out also in the heavy-duty field. It is interesting to note that Shuler is maintaining the vertical knuckle to avoid steering difficulties, especially at maximum turning angles, which are sometimes obtained with the inclined knuckle. Theoretically, there should be difficulties under severe braking application, although experience does not bear this out. The Wisconsin Axle Co. is in production on a front driving axle in which the Rzeppa universal-joint is used.

Wheels, Rims and Tires

The trend toward tires of small over-all diameters and larger cross-section has been very pronounced, so that, with only a few exceptions, the entire passenger-car industry has gone to 17 or 18-in. diameter wheels. The wire wheel continues to be very popular and its fabrication has been simplified by special machinery such as has been recently developed by Budd. Such cars as the Cadillac use the wire wheel as standard equipment. Where wood wheels are used they are usually demountable at the hub. Nash conceals the hub bolts by a cover plate. In imitation of the wood wheel, Budd is producing a wheel made of low-carbon steel with a natural-wood finish or lacquered the same as the body color, or in stainless steel such as is used by the Pierce-Arrow company. The wheel is 6 lb. lighter than the equivalent wood wheel, four to five times stronger and permits decoration at a greatly lowered cost. Large hub-caps are prevalent, with the Pierce and Graham as worthy examples.

There has been a landslide to the drop-center rim. The valve in most cases comes out through a hole in a corner of the well at an angle rather than radially within the plane of the wheel.

Passenger-car tires now run up to 7.00 and 7.50-in. sizes. Some of the car manufacturers have succeeded in getting their cars so quiet that tire noise becomes very evident. The demand for quiet tires is being met by changes in tread-design details. It is fairly well understood that, whatever revisions are to be made in the Model-A Ford, it will include a change in the tire size from 4.75-19 to 5.25-18. Chevrolet, Plymouth, Pontiac, Willys and a few other makes take this size. The 4.75 and 5.00 tires will be obsolete insofar as original equipment is concerned. This change has necessitated manufacturers in the next class getting away from the 5.00 and 5.25 tires and stepping up their equipment to a 5.50 section and so on all through the line. The Seiberling triple-tread air-cooled tire is an interesting new development, as well as the Goodyear Air-Wheel, in which 8 to 12 lb. pressure is kept in the rear tires and 15 to 20 lb. in the front. A 9.00-13 tire is in production for Fords and Chevrolets and is mounted on a special wheel that is interchangeable at the hub with standard equipment.

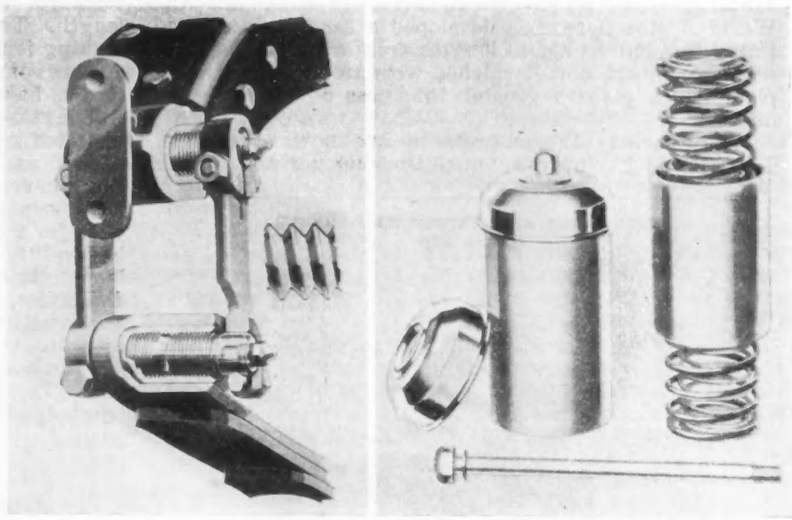
Suspension

The rubber-block spring mounting is rapidly declining, while the rubber-bushing type is increasing. Cadillac and Buick are using threaded instead of plain shackle bolts. They are threaded into the steel spring bushing so as to leave considerable side clearance. Rattles are eliminated to a large extent and the threads, 10 to the

inch, assist in retaining the lubricant. In the Pierce-Arrow and the large Studebaker models the Fafnir ball-bearing shackle is continued.

The spring leaves on the Buick have their ends curled and the corners are trimmed to give a full bearing surface. Outboard mounting of the spring as used on the Graham allows the same clearance over the front axle with lower frame height. The front springs are spaced 8 in. and the rear springs 6 in. farther apart over the previous model, reducing the angle of tilt for a given spring deflection.

In the heavy-duty field, the International Harvester Co. has developed a special tandem-spring mounting, with one semi-elliptic spring above and the other below the axle housing. The aim was to maintain maximum frame width in view of the limitations imposed by dual balloon tires. Mounting the rear end of the frame directly on the walking-beam on the two-rear-axle bogie unit without any springs is practiced in the LaFrance-Republic and Maccar, which depend entirely upon the resiliency of the tires and the rocker effect of the walking-beams.

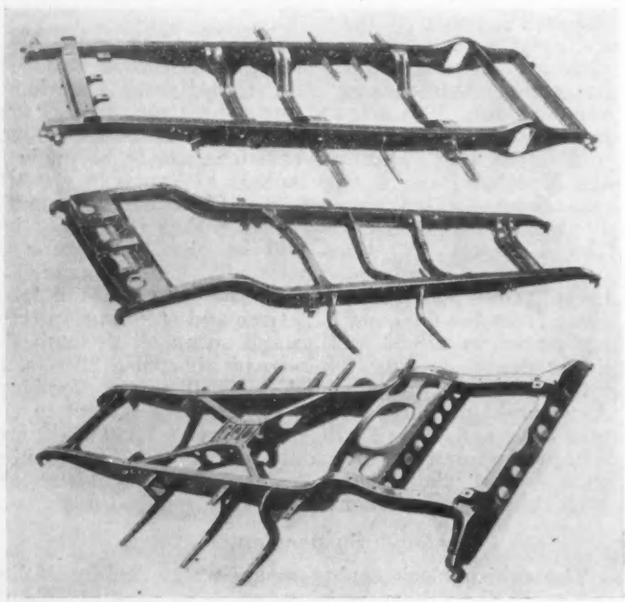


BUICK THREADED SHACKLE-BOLT AND PACKARD FRONT-END STABILIZER

Frame

Frames have undergone considerable development in the last year, and rigidity is often obtained by box-section or X cross-members. The Cadillac has box-type cross-members. Hudson and Pierce-Arrow have this construction for the front and Pierce-Arrow and Lincoln for the center cross-member, supplemented in the latter case by large angle-plates.

The Hudson, Essex and Rockne are provided with X cross-members, which type of construction was inaugurated by Cord and Auburn. In most cases a cross-member has been added at the rear of the transmission, supporting the powerplant at this point. The Chevrolet has a front cross-member of double channel section which spreads out at the ends to the entire width of the blank. To obtain rigidity in the side rails, the Pierce-Arrow has a box section from the center cross-member forward to the front-spring horns, with an opposed channel member fitting inside of the main channel, to which it is cold-riveted and arc-welded at various points. The deepest section of the frame rail is carried well forward to a point ahead of the front kick-up. In the case of the Hudson side rail, the maximum depth is at the front end of the body, where the maximum stress occurs. At this point is located the rear-engine-support cross-member, the engine being attached to a vertical flange which immediately becomes horizontal between the points of engine support. In the Packard side rail, the front kick-up is made in two steps to permit the proper positioning of the steering arm and steering-gear connecting-rod, the spring hangers and rear engine mounting. In the Chevrolet side rails, a raised rib is stamped at each side of a front-spring rear-bracket lug to prevent undue reflection at this point.



GRAHAM, CHEVROLET AND HUDSON FRAMES

Note Banjo Formation at Rear Axle in the Graham, Double-Channel Front Cross-Member in the Chevrolet, and X Cross-Member in the Hudson

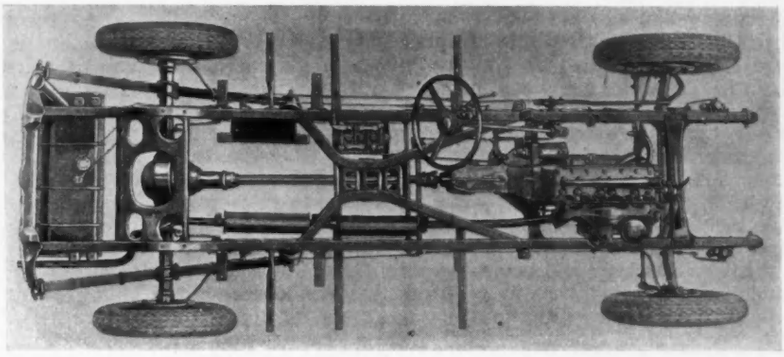
To combat lack of torsional rigidity of the side rails ahead of the cowl, the Packard and Pierce-Arrow companies tie together the radiator shell and fenders by means of a brace extending therebetween and supporting the head-lamps. The customary tie bar between the fenders is retained. In this way the entire front end is tied together and united to the cowl by means of the hood and a heavy V-bracing from the dash to the radiator. Packard goes a step further with the "harmonic front-end stabilizer" consisting of a mass of definite frequency in the form of a lead weight on a cast-iron core mounted between two sets of calibrated concentric springs. Such a unit is located at each end of the front bumper.

Rather than to attempt to tie the whole front end together, Chevrolet engineers use a single fender-support unit which holds the front fenders, radiator and head-lamps and supports these parts at a neutral point in the center of the front cross-member by a rubber mounting. A rigid two-bar tie-rod runs between the fenders and is braced on each side to the radiator shell, which is reinforced inside its upper portion. A V brace goes to the dash from the radiator shell.

Of considerable interest is the Graham "banjo" formation at the rear axle, an opening in the banjo section permitting axle movement under spring deflection. The

kick-up is considerably reduced by this construction and there are rubber bumpers at the top and bottom of the opening. The car can be jacked from the rear end of the frame, as the frame raises the axle as soon as the lower bumper comes in contact with it. Two deep U-section cross-members are slung under the frame and extend out to support the running-board. The low height of the frame at front and rear permits a low center of gravity of the body.

There is a trend away from the maximum possible frame width and we now find outriggers for body mounting on the Pierce-Arrow, Lincoln, Studebaker and Rockne. Considerable interest is evident in the welding of chassis frames, and many of the box-section constructions now used will inaugurate an expansion that is bound to come. Truck frames are now being made without a fish-belly reinforcement by making the channel height conform to the previous contour of the reinforcement.



ESSEX CHASSIS, SHOWING X CROSS-MEMBER IN THE MIDDLE

Control

An increase is noticeable in the mounting of the clutch and brake pedals on the frame side-rail so as to be independent of the powerplant vibrations, which are becoming more pronounced with the softer rubber mountings used and, in the extreme case, the Plymouth powerplant which oscillates through a considerable angle. The Plymouth gearshift and transmission levers are mounted on the cross-member and are not in contact with the powerplant except in the case of the gearshift lever when gears are being shifted. The accelerator pedal is located at a neutral point. The side-rail pedal mounting is also used by Packard, with a lead from the central lubricating system, and on the Rockne and Studebaker. The Packard accelerator-pedal linkage has been changed so that the first half of the travel opens the throttle only one-third for finer traffic control. The Buick has a rubber-covered treadle-type accelerator pedal and provides rubber pads on the pedals.

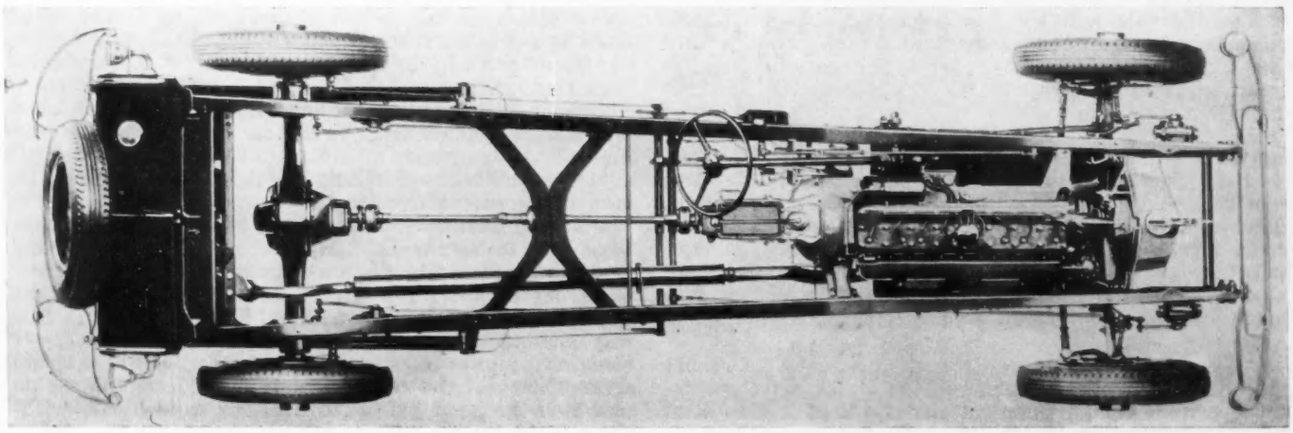
The throttle friction has been moved on the Buick to the bottom of the steering-gear. An adjustment is now provided at the rear end of the steering-gear connecting-rod so that, with different positions of the adjustable column, the three-spoke steering-wheel can be kept in the proper position to maintain an unobstructed view of the instruments. With the outboard spring mounting of the Graham, the steering-gear connecting-rod is carried above the spring, which protects it from damage from below. Gemmer has a double-roller design to supplant the single.

A very interesting development is on the Model-40 Yellow coach in which the steering-gear is mounted horizontally on the axle pad inside the left spring-seat. A short steering-gear connecting-rod extends to each spindle steering-arm and a small propeller-shaft with two joints conveys motion from the base of the steering column to the worm and sector on the axle. Mack has developed an hydraulic steering-gear booster consisting of an engine-driven rotary vane-pump from which oil under pressure is led to one side or the other of a piston or permitted to bypass according to the position of a spool valve in the cylinder head having a 1/16-in. travel forward or back. This valve is controlled by a ball-stud acted upon by a primary rod connected to the conventional steering-gear. The mechanism is protected by a safety bypass.

Besides the free-wheeling control, a "ride regulator" has been added which consists of a lever on the dash or steering column to provide a varying resistance of the hydraulic shock-absorbers. With such added controls, it does not seem that we are approaching automatic control of our vehicles, but no doubt this will come in time when responsive means will be found to supplement manual control.

Equipment

The single-bar bumper predominates. The front license-bracket has been carried to one side on the Nash and Buick so as not to obstruct the lines of the radiator. The use of two horns of the trumpet type, usually chromium-plated and one mounted below each headlamp, is seen on the Cadillac, Buick, Olds and Pierce-



PACKARD CHASSIS, SHOWING X CROSS-MEMBER AND THREE-JOINT PROPELLER-SHAFT

Arrow. The Cadillac has concealed connections, and the Chevrolet has a single trumpet horn mounted below the left head-lamp. A four-beam asymmetrical head-lighting system has been brought out by Cadillac, in which triple-filament 21-21-32-cp. lamps are used. Separate beams are provided for country driving, country passing, city driving and city passing. All beams are controlled from the steering-wheel. A tail-lamp having a safety reflex element to warn approaching cars from the rear even if the lamp is out is used on the Cadillac, Buick and Studebaker. Dual tail-lamps are used by Cadillac, Buick and Lincoln. A "blinker" stop-light in which the rapid flashes are caused by a pendulum-actuated, alloy point-wiping contact has been brought out by the Mitchell Specialty Co. Packard has raised the battery box to the level of the tool-box on the opposite side. Both covers are provided with a lock which takes the ignition key.

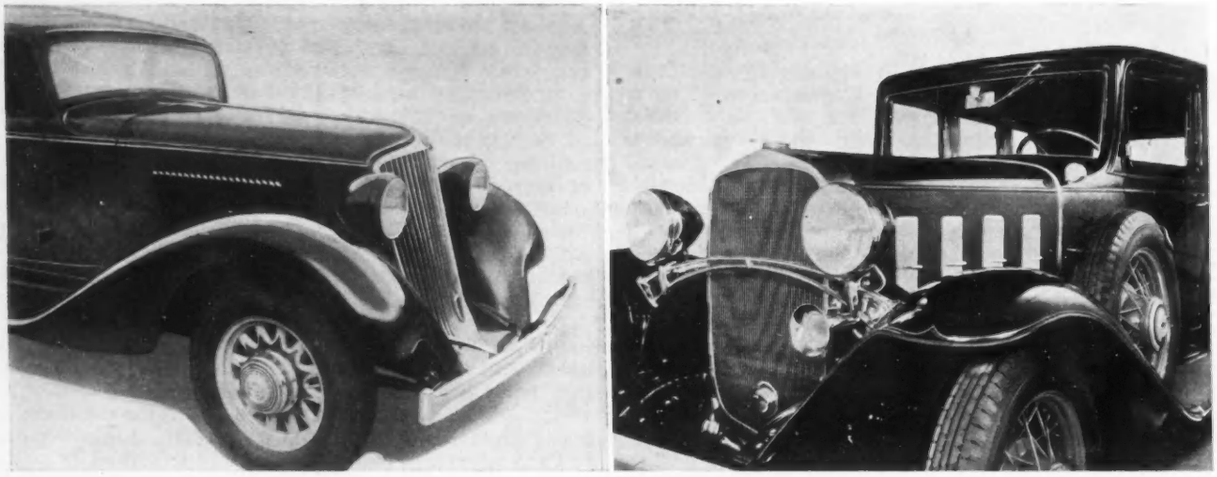
The Packard central lubricating system has been extended to include the clutch throwout-shaft bearing, clutch and brake pedals and the universal center-housing, making 40 points in all. The Loxite lubricating coupling and fitting has been introduced, in which the coupling is of steel. The unit can withstand a pressure of 10,000 lb. per sq. in. and does not depend on grease pressure for opening the fitting check-valve.

Considerable activity has been expended on shock-absorbers in order to provide ride control. The Packard has a three-position control, while the Cadillac has five positions. Other cars have an infinite range. The control linkage is similar to a four-wheel-brake hook-up of either the rod or cable type. The Cadillac regulator varies the spring pressure on the shock-absorber valves. In the case of Pierce-Arrow and Buick, the needle-valve can be lowered or raised to restrict or open the orifice. Thermostatic control also has been developed in order to change the size of the orifice with changes in temperature. Houdaille provides an automatic system with thermostatic and dynamic controls, the latter compensating instantaneously for changes in speed and road surface.

All instruments and controls are located on the left side of the instrument board in the Buick, with a lockable package compartment at the right, as is also done in the Cadillac, in which the controls are kept in the center. The Packard has all instruments and controls except the ride control at the center. The package compartment is at the right and the left side is blank. The use of convex lenses over the dials of all instruments eliminates glare and improves visibility and the appearance of the panel. This practice extends from Chevrolet up. Studebaker's electric gasoline gage can be read with the ignition off by depressing a button. In place of an ammeter and oil gage, the Hudson and Essex have red lights which indicate too low a charging rate or oil-pump failure. On the more expensive models of these makes, the horn button can be turned up to expose a vanity mirror. The Hudson instruments are placed high so as to be easily legible and increase safety by necessitating less angular movement of the driver's eyes from the road position.

Sheet Metal

Considerable effort has been expended in smoothing out sheet-metal work, the avoidance of sharp corners and the enclosing of chassis parts. Fenders and hood sills are often in one piece. The outstanding fender development is seen in the Graham, in which the fenders fully conceal the frame and running-gear, only the wheels being visible. To the rear of the wheels, the crown is brought down in a front apron which drops in line with the running-board. Buick has eliminated the cover plates in the side splashers by a relocation of the chassis-lubricating fittings. On the Pierce-Arrow the front frame-horns are enclosed by sheet-metal stampings lacquered to match the fenders.

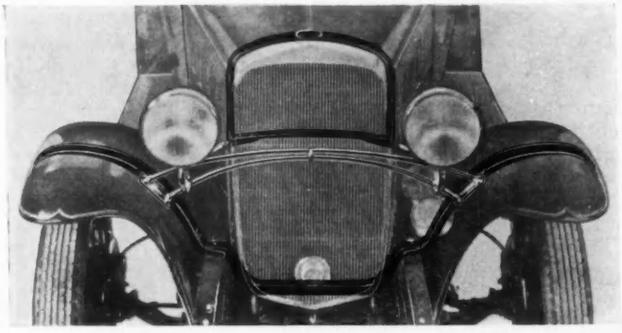


TYPES OF FRONT-END TREATMENT

The Graham (Left) Shows New Fender and Hood Style. The Chevrolet Has Hood Doors and Integral Grille

Door ventilators in the hood have entirely replaced louvers and lend elegance to the car as well as providing under-hood temperature control. These hood side ventilators are thermostatically controlled in the Lincoln, as are the radiator shutters.

What appears to be the coming hood design has been developed by Graham. The hood eliminates the usual radiator-shell width, the shell being exposed only from the front except for a narrow center strip which runs to the cowl. Continuity of line is brought about in this way and adds to the speed appearance of the car. It remains only to combine this design with the hood styles shown at the recent New York Automobile Salon in which the hood tops extend to the windshields without a break in line. Most cars are now using the single, central, concealed type of hood latch and handle which



PHANTOM VIEW OF CHEVROLET FRONT

Radiator, Head-Lamps and Fenders Are Tied Together at "One Point" on Front Cross-Member

locks the hood against the dash and radiator shell, increasing its effectiveness as a brace for the radiator.

Body

The "tear-drop" car does not lend itself to present concepts of beauty. The public must become educated to its possibilities in gradual steps, while the manufacturer preserves a balance between aerodynamic efficiency and that illusive, changing element called beauty. Some of the new cars show considerable development along the general lines of reducing air resistance except at the rear end, where further development work lies. The windshield is now being given more slope, in the neighborhood of 10 deg. from the vertical. The roof is well rounded off and the exterior visor is becoming obsolete even in the low-price cars such as the Chevrolet, in which a universally adjustable interior visor is provided to protect the driver. Visors are now so located as not to interfere with rear-mirror vision. The "aerodynamic" windshield inaugurated last year by Reo is now the vogue. For balanced design, the slope of the back edge of the rear window corresponds with the forward slope of the windshield.

A tendency in the higher-priced bodies is to continue the forward edge of the door in a sloping line to the bottom, while in the lower-priced class such as Chevrolet and Rockne the door is vertical between the hinges. The Chevrolet door extends to the bottom of the sill. In the five-passenger closed Studebaker, an exceptionally wide door is used, extending from the front pillar, where it is hinged, to a point midway between the back of the front seats and the front of the rear cross seat. Windows are made shallower with the lower over-all body and car height. Studebaker uses safety glass all around in all models.

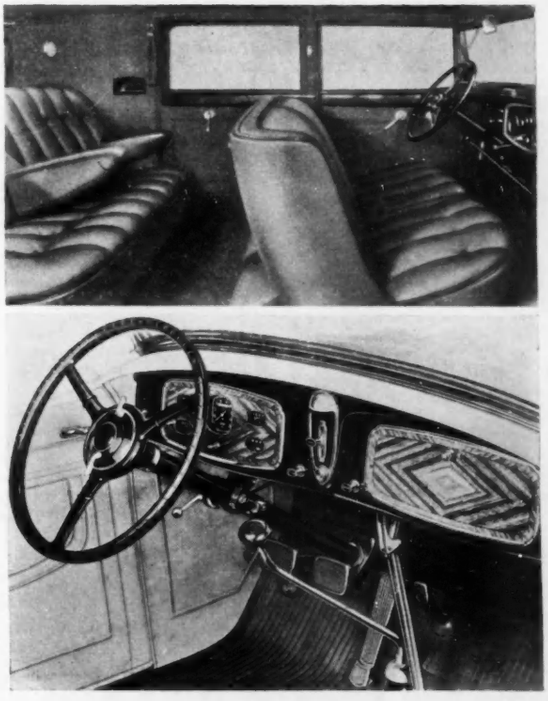
The Graham windshield hinge is totally concealed within the header, which also hides the mechanism of the two windshield cleaners. The shafts of the cleaners project through the forward curved roof-panel instead of through the windshield frame. In the Packard the windshield brackets are concealed within the windshield frame for greater neatness. Most convertible and open models have the wipers mounted at the base of the windshield. Roadsters have tops that are completely concealed when down.

Steel is being used in greater proportion. In the Hudson and Essex framework, the pillars and rails and their supporting structures are all individual pieces of box-girder construction. At the top of the pillars are copper-zinc-alloy die castings which tie together the roof rails and pillars; at their base either structural or cast feet provide a connection to the wood sill, which is only a filler, useful for attaching the body to the frame and having no part in the structural entity of the body. Padding is placed over the top-bows to muffle the top.

In the wood framing of the Graham body, heavy bolts are used instead of wood-screws. Most of the Fisher bodies have all moldings stamped directly into the body panels. All Buick panels are welded together except the rocker panel between the doors, which is left open to ensure flexibility. Free-wheeling, with its coasting periods, has permitted to become evident body and other noises that hitherto have been unsuspected. The silencing of bodies has been given considerable consideration and ties in with the heat-insulating problem, the dash and floor as well as the panels being covered. A sprayed-on asphaltum composition is used by Nash, while Packard covers the panels with cardboard cemented on. The Edward G. Budd Mfg. Co. has developed a new material called Silento to be pasted on the inside of the panels. The Hudson company uses a fibrous jute composition. Pressure feet of an adjustable type press the jute pads against the panels. Every flat surface is broken by beading or padding so that it is permanently muffled.

To prevent squeaks, insulation material is used in body joints wherever possible. Materials used are felt, wool, cork, rubber, rubberized fabric, anti-squeak strips, rubber dough, dum-dum and cord-welt. Floor-boards of five-ply laminated wood instead of metal and asbestos coverings are utilized to eliminate engine heat and noise. The Packard is provided with a dash of heavy-gage steel with 3/4 in. insulating material ahead of it and covered by a false back.

Openings around controls usually are closed by heavy felt or, as in the case of the Pierce-Arrow, the enclosures are surrounded with sponge rubber and



INTERIOR TREATMENT OF THE PACKARD AND BUICK

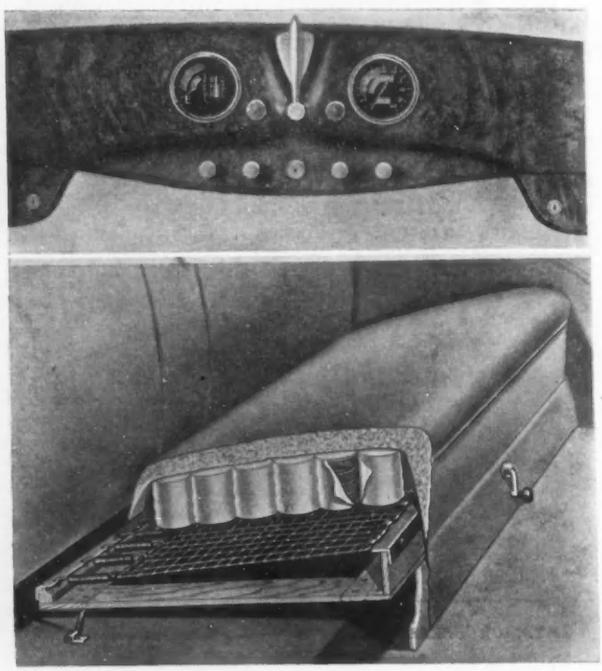
Both Have a Ride-Control Lever on the Steering Column. Note (Below) Buick Wizard-Control Button and Package Compartment at the Right in the Instrument Board

felt pads. Wool-faced rubber mats are also popular for the driving compartment. They are designed to provide better appearance and heat and noise insulation. The mats have a wool facing cured onto the rubber, the wool being waterproofed.

In the Fisher bodies a new seat-adjustment mechanism is used which is operated by raising a handle on the left side, whereupon the seat can be rolled either forward or backward and then locked in place.

Studebaker has standardized on seat widths for all models, front and rear seats being 48½ in. wide at the cushion, front seats 53 in. wide at shoulder height and rear seats 55 in. at the same point. In the Hudson and Essex the vertical coil springs rest upon a wire-mesh foundation hinged forward and held at the rear by horizontal springs, giving the seat added resiliency. Arm rests are provided on both sides and can be folded out of the way if desired. The Nash seat-cushion spiral springs are silenced by cotton pads.

The Fisher bodies are being fitted with door hinges having bronze or brass bushings, depending upon the price class. They are pressed into the pinhole of the door member of the hinge and an oil hole is provided for lubrication. Ground hinge-pins are pressed into the body member so that they oscillate in the bushings. Chevrolet doors have two hinges instead of three, the appearance being improved by setting them at points of less projection and they are easier to align. In the case of the Buick and Graham, all the doors can be locked from inside the car but the driver cannot lock himself out without using the key. The Mitchell Specialty Co. has a dovetail in which the hollow wedge member secured in the door is provided with a wick impregnated with oil and graphite. This wedge enters between two spring-loaded bumpers fastened to the door frame which are made of either Bakelite or metal. The Graham doors have a dovetail at the top in addition to the usual dovetail at the pillar.



HUDSON INSTRUMENT BOARD AND SEAT-CUSHION CONSTRUCTION

To give accessibility to the interior structure of the body, the Graham door-header panels are detachable steel channel sections held in place with bolts. When removed, the wiring, windshield-wiper tubing and framework bolts can be reached. The trim panels on the inside of the doors are held in place by spring clips. The panel can be removed by forcing a screwdriver under the edge of the trim and prying the clips out of their sockets in the metal of the door, thus exposing windshield, glass and glass channels. There are concealed window shades and rollers in the rear-quarter windows. The rollers are contained in the lower garnish moldings, and the fabric of the shade runs through a narrow slit in the molding. The Hudson door pockets are fitted with their slide fasteners on an arc so that they will retain their shape.

Packard has eliminated the use of rubber body-shims. Because of the outrigger mounting, the Pierce-Arrow and Studebaker body sills are of the vertical type. In each case they are mounted on the outriggers so that the bottom of the sill is on the neutral axis of the frame side-rail. Cork shims are employed at this mounting point in the Pierce-Arrow.

The use of chromium is being suppressed with the object of giving greater continuity of line. The Graham furnishes an excellent example, in which color is used instead. The head-lamps have only a narrow plated bead on the rims and appear to be part of the car instead of being attached. Chromium-plating is used only on the radiator grille, hub-caps, door handles, bumpers, windshield frame and the head-lamp rims. Interior colors are made to harmonize with the body color, and the Hudson company goes even to the extreme of making the window channels harmonize as well.

Motorcoach and Truck

A prominent development in the motorcoach field is new Yellow Model-40 all-metal coach. Aluminum alloy is used for body members and frame sections, this being a unit body-and-frame construction. Heat-treated drop-forged aluminum side-posts are used. The makers claim that they saved at least 2 tons over the conventional steel construction. The engine, transmission and differential case are all in one unit, removable from the rear. The rear axle is tubular, with an offset center section having end castings that form the wheel spindles and brake anchorage. A DeDion drive is used, with the outer joint within a relatively large hub. The weight distribution has been worked out so that one-third comes on the single front tires and two-thirds on the dual rear tires.

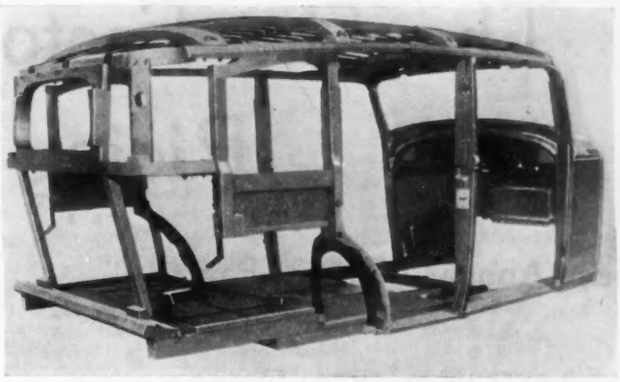
The Bender bodies on White chassis have a new under-body construction eliminating outriggers. Z-type steel splash guard-rails extend entirely around the under structure, with the top flange riveted to cross channel-units each of which consists of two channels placed back to back with a wood filler between. The channel members are secured to the chassis frame. A heavy steel wheel-house is built into the guard rails. Side pillars are bolted to the outside of the Z member and rest on the out-turned bottom flange.

In the truck field, Fageol has eliminated 2900 lb. from the 10-ton model, of which 960 lb. is unsprung weight, by the use of aluminum for axle housings, radius rods, frame rails, brackets and cab sheet metal. A new six-wheel truck with four driving wheels at the rear has been developed by Sterling. A jackshaft is located between the axles, with side-by-side chains extending fore and aft. Individual radius-rods

position each wheel from the jackshaft. Lateral stability, in view of the open-end swivel-mounted springs, is obtained by a transverse radius-rod to each axle from the frame. Krohn compensators are used between the drives for each axle and also between the individual wheels.

It is interesting to note the complete axle program of the Timken-Detroit Axle Co., which takes in, besides its well-known line, front-driven and dead or trailer axles. Interchangeability of parts is achieved throughout the whole series. Many of the truck manufacturers have now gone into trailer and semi-trailer construction, which field is receiving a great impetus. The house-to-house delivery truck has been given considerable study and this type is now being built with special drop frames to meet the requirements of the service.

It is regretted that the early form-closing date of the S.A.E. JOURNAL prevents presenting in this issue a complete story of all the new vehicles. However, it is believed that, from the material presented, the outstanding trends will be evident. During the last year the engineer has been called upon to help the industry, and it is very clear that he has responded most generously and achieved most effectively.



BODY FRAMEWORK OF THE GRAHAM
Note the Very Slight Kick-up Required by the New Frame

Canada's New National Aeronautic Laboratories

SCIENTIFIC KNOWLEDGE and research play a more important part in industrial development today than ever before. While most industries are indebted to scientific knowledge and research, none are more so than aviation. The rapid development in mechanical flight and aircraft construction during the last 20 years has been very largely the result of invaluable research work in the science of aeronautics. Further advancement in air transportation, aviation and the industry is dependent on the provision of adequate scientific research and experimental data. Future research in aeronautics may well result in advances greater than any yet made.

In Canada, until the present time, there has been but one small aeronautic laboratory, that of the University of Toronto. Since the establishment of this laboratory in 1917, a number of problems of interest in the design of Canadian aircraft have been investigated and assistance has been given constructors in developing aircraft.

With the rapid growth of Canadian aviation and the increasing importance of the aircraft industry, more extensive laboratory facilities are a necessity if sound progress is to be made and a self-contained industry built up. The National Research Council therefore has undertaken, with the approval of the Subcommittee of the Privy Council for Industrial and Scientific Research, to provide facilities for aeronautic research in the National Research Laboratories now being established at Ottawa.

While the whole field of aeronautic research includes most branches of engineering, provision is being made in the aeronautic laboratories only for aerodynamic, hydrodynamic and powerplant research and testing. Other branches, such as strength of materials, metallurgy and chemistry, will be taken care of as occasion arises in the engineering, physical and chemical divisions of the National Research Laboratories.

The building in which the wind-tunnel was to be housed was already in existence and was of such form that a double-return tunnel, with the plane of the circuits horizontal, could be housed to better advantage than a single return. The dimensions of the building were sufficient to permit of the construction of a wind-tunnel having an airstream that is not larger than 9 ft. in diameter.

A small hydraulic powerplant having a minimum continuous generating capacity of 600 hp. at low water was available on the property.

Accordingly the decision was made to construct a 9-ft. diameter, 600-hp., open-jet, double-return wind-tunnel. Design was started in September, 1929, and construction in November, 1929. The tunnel proper was completed with the exception of the installation of the vanes and propeller before the end of 1930.

As flying-boats and aircraft fitted with floats are extensively used in Canada, particularly in the north country where the numerous lakes and rivers provide landing places for such craft in country lacking other landing facilities, improvement of floats and hulls and of the performance of aircraft fitted with them is of considerable importance in the Dominion. For this work a testing tank is essential.

In fixing on the dimensions of the Ottawa tank, local factors had to be considered. As in the case of the tunnel, a building was available in which a tank 394 ft. 2 in. long by 9 ft. wide by 6 ft. deep has been built. It is constructed of reinforced concrete and the bottom of the tank is about 4 ft. below the floor of the building. The 80-lb. railroad rails on which the carriage runs are carried on H beams resting on the cast-iron caps of concrete piers extending above the tank sides.

As the speeds provided for in the design are too high to permit of securing the necessary acceleration by traction, the carriage is to be drawn along the tank by steel cables. Owing to the very short time available for measurement and observation during the constant-speed portion of the run, the towing balance must necessarily record automatically. The actual design of the balance embodies a number of new features. It is being constructed throughout of metal.

From an aeronautical standpoint, the laboratories provide the Government with urgently needed testing facilities and relieves the Canadian aircraft industry of serious handicaps under which it has previously labored.—From a Canadian Section paper by Prof. J. H. Parkin, assistant director, division of physics, National Research Council of Canada.

The Tire Factor in Automobile Riding-Quality

Semi-Annual Meeting Paper

By Roy W. Brown[1]

METHODS are outlined for measuring the characteristics of tires that affect riding-qualities, and typical curves showing rate of deflection and contact area versus tire size are presented. Coordination of service performance with simple laboratory tests is illustrated. Means of securing the inter-effect of tires and springs are outlined and curves of typical axle-body frequency versus tire size are shown. Use of the solenoid accelerometer in conjunction with equipment for interpretation of physical effect of accelerations is suggested for service tests. Secondary riding-quality factors such as tire traction, horsepower and rim diameter are discussed and numerous others mentioned. The influence of tread design and other factors of tire design is indicated.

Discussers raise questions regarding change in inflation pressure with a change to a rim of smaller diameter and a tire of larger section; absence in the low-pressure cord tire of the damping effect of friction in the carcass of the high-pressure woven-fabric tire; effect on tire deflection due to use of wider rims; portion of the load supported by stiffness of the tire walls; distribution of pressure over area of tread contact, increased pressure at the edges of the tread giving better traction; increase of coefficient of friction by non-skid tread; reduction of noise by use of rib-type tread; and effect of present tendency to use thicker tubes and heavier super-tires.

Additional research on how to rate the load capacity of tires of different diameter is said to be needed.

Instrumental research is asserted already to have shown that certain upholstery materials have marked value in reducing noise in the body.

Avoidance of synchronism of periods of the front and rear-end unsprung weight with each other and with the car body is commented upon as important to riding comfort.

DESIRE for higher speed with safety and comfort has stimulated tire development during recent years to such an extent that present constructions have appreciably different characteristics than tires of former years. For the same reasons other elastic portions of the chassis have undergone numerous changes. Since the difference between the shock the passenger receives and the blow caused by the road irregularity is largely dependent upon the combined cushioning properties of tire, spring, shock-absorber and seat cushion, it is evident that effective design can be based only upon knowledge of the elastic properties of these portions of the vehicle and their interrelation.

Several instruments developed recently provide means for measuring suspension performance[2]. It is believed that typical modern-tire performance data will assist in more effective use of these instruments and add to available information on riding-qualities.

Some Tire Characteristics

The excellent riding-qualities of pneumatic tires result from ability of the tire to deflect relatively large amounts when loaded. Static deflection with varying load can readily be determined in the laboratory with conventional compression-test machines. The area of the tire surface in contact with the road can be simultaneously determined by any of several transfer methods. Fig. 1 gives the typical relation of rate of deflection, contact area and inflation pressure to tire size for a medium-size passenger-car. These data enable the engineer to approximate at once the optimum tire size.

Results from several years' research indicate the rate of deflection over the range 100 to 200 per cent of static load for pneumatic tires to be the most readily obtained static characteristic representative of actual performance under service conditions. Rate is a more accurate index of the riding-qualities of a tire than is

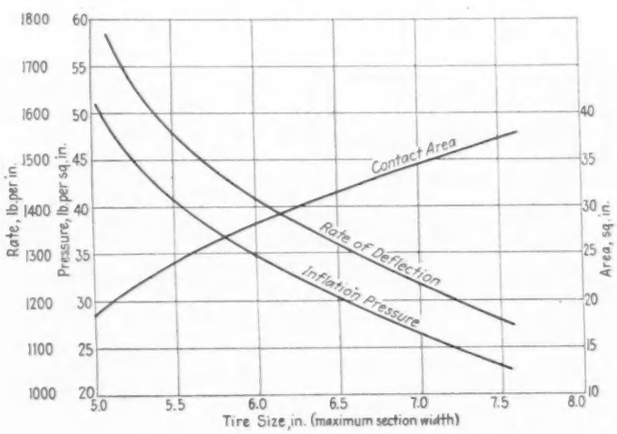


FIG. 1—RIDING-QUALITY PROPERTIES OF TIRES

Rate of Deflection Is an Index of Service Performance. Contact Area Determines Traction and Unit-Area Load on the Road Surface. Conditions: Medium Size Passenger-Car, Six-Ply Tires, Rim Widths as Ordinarily Used and Inflation for Equal Percentage Deflection

[1] M.S.A.E.—In charge of engineering laboratories, Firestone Tire & Rubber Co., Akron, Ohio.

[2] See S.A.E. JOURNAL, May, 1931, p. 577.

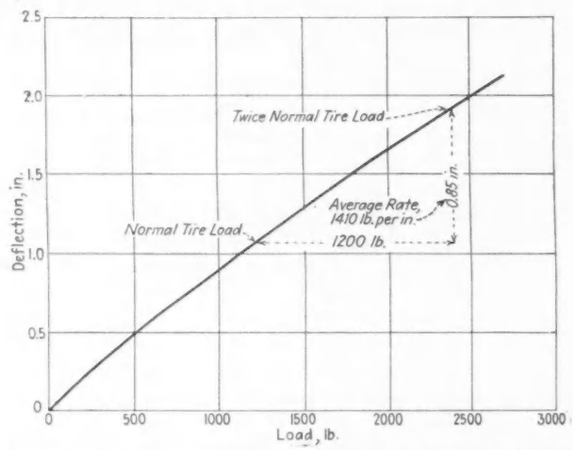


FIG. 2—PNEUMATIC-TIRE LOAD-DEFLECTION CHARACTERISTICS

Note the Non-Uniformity of Deflection with Increasing Load. The Average Rate of Deflection between Normal and Twice-Normal Load Indicates the Riding-Qualities of the Tire

total deflection, since the deflection of tires, especially cushion and solid tires, does not increase uniformly with increasing load. An index, to be usable, must represent conditions as they occur in actual service. Use of the Firestone solenoid accelerometer on cars on the road in typical service indicates that the representative pneumatic-tire load range is from 100 to 200 per cent of the stationary wheel-load and has substantiated the authenticity of the use of rate of deflection as a criterion of riding-qualities.

A typical pneumatic-tire load-deflection curve is shown in Fig. 2. The method of determining the average rate is also indicated.

Tire and Spring Inter-Effects

Much effort has been exerted to establish a simple relationship between the natural frequency of the front and rear springs and between the frequencies of each with varying tire equipments. No acceptable solution covering all conditions has as yet been found.

[3] See *General Electric Review*, August, 1924.

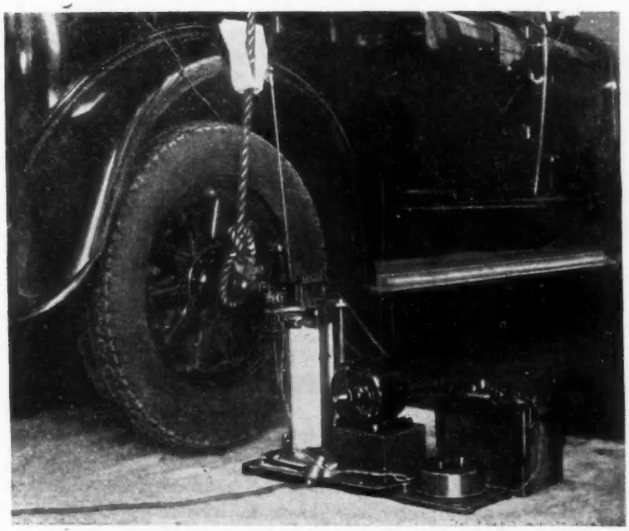


FIG. 3—METHOD OF MEASURING AXLE AND BODY DISPLACEMENT

A Chronograph Is Mounted Near the Wheel, with Pencil Mechanism Attached to Axle and Body. A Record Is Made of Movement When the Axle Falls after Cutting the Rope

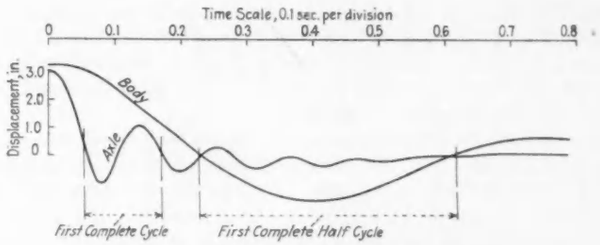


FIG. 4—DISPLACEMENT-TIME CHART

This Record Shows the Relative Position of the Axle and the Body from a Free Fall of 3 In. Frequency May Be Obtained from the Time Taken To Complete an Oscillation

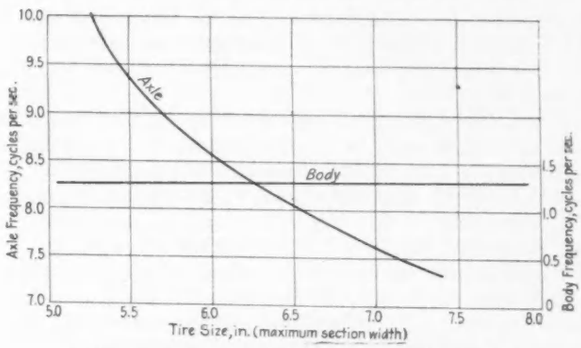


FIG. 5—AXLE-BODY OSCILLATION FREQUENCY

These Curves, Computed from a Series of Displacement Records, Indicate the Effect of Tire Size. In This Case No Appreciable Variation in Body Frequency Occurs

Much information can be quickly secured by measuring the vertical movement of both body and axle when subjected to a repeatable shock condition such as dropping the axle a known distance. Determination of body and axle frequency from the records obtained will show any objectionable interaction. A convenient method used for a number of years is illustrated in Fig. 3, and a typical record is shown in Fig. 4.

Axle and body frequency as affected by tire size can readily be determined by a series of tests. The results of such a series are presented in Fig. 5 for conditions given in Fig. 1. It is significant that body frequency does not vary appreciably throughout the range of tire sizes. Hence, in this instance, any tire may be used without change in other elastic portions of the chassis. The matter of final decision as to tire size resolves itself into balancing the properties given in Fig. 1 against other considerations such as appearance and cost.

It is believed that a method developed for determining the natural frequency of turbine blades[3] could be used advantageously for securing similar results. With this, one or more wheels could be caused to vibrate continuously at a frequency dependent upon the characteristics of the tire, spring, axle load and body load. Synchronous vibration effects would be revealed at once. Natural frequencies would be obtainable directly from the instrument tachometer.

How Service Tests Can Be Made

The laboratory tests enumerated may quite definitely answer the question regarding the influence of the tire

on the ride, or possibly the results may indicate that either of two sizes or types of tire approximate the desired performance. For this and other reasons, a final performance measurement under selected actual-service conditions is highly desirable.

The solenoid accelerometer provides a means of counting the number of accelerations and indicating their magnitude. A test run should be repeated a number of times to assure average results. Data may conveniently be presented graphically showing the number of accelerations per mile versus accelerations in feet per second per second. Experience has demonstrated that differences as small as the equivalent of 5-lb. inflation pressure can be consistently detected. Use of the accerometer eliminates, so far as vibrations due to road irregularities are concerned, the guesswork incidental to the time-honored method of trained riding-comfort observers.

No definite method of interpreting accelerations in terms of discomfort to the passenger is available as yet. Abroad, the rate of change of accerelation is thought to be an important factor[4]. Completion of the work which Dr. F. A. Moss[5] has under way promises much as to the interrelation of vibrations, discomfort and fatigue. Experience has indicated that, for present vehicles, variations in riding-qualities may safely be assumed to be proportional to the square of the acceleration to which the passenger is subjected. Service tests usually are conducted to determine which of two or three selected equipments is best. Without exception, the equipment showing the lower number of accelerations of smaller value has provided more comfortable riding.

Secondary Causes of Riding Discomfort

The foregoing discussion has been confined to primary vertical effects produced by road irregularities. In addition, numerous conditions of discomfort of secondary importance arise from fore-and-aft and lateral accelerations; high-frequency low-amplitude gear and engine vibrations; noise and odor; visual effects and numerous other conditions of possible psychological significance.

Among the latter is what might be called the "sense of security," which is so notably lacking in back-seat drivers. This is influenced by tire traction or non-skid properties, a subject on which little exact information is available. The more general use of higher speeds increases the significance of traction, as is made evident by consideration now being given to the design and nature of road surfaces.

The recent increase in horsepower and engine acceleration has so increased torque loads on the tire that this factor must now be considered with respect to riding-qualities. In general, increase of tire size for the higher powers now used seems necessary. The effect appears to be an increase in the rate of deflection of the tire for a given load and inflation pressure.

Small rim-diameters, with a tendency toward further decrease in diameter, is a factor meriting consideration. The load-carrying capacity of the smaller rims is less for equivalent tire sections. Hence, if the same section is used, inflation for equal service must be higher, with consequent decrease in riding-qualities.

The effect of any one of these secondary factors probably is comparatively small. Measurement of some of them can be accomplished by methods already outlined. Others can be measured by adaptation of available instruments. Determinations of only a few remain in the research class. Of the latter, only traction appears to be of appreciably practical significance.

Influence of Design

Tires with thicker, flatter treads and the necessary stiff body-construction designed to provide greater resistance to tread wear do so with decreased riding-comfort, as is indicated at once by rate-of-deflection curves. Cord angle, the amount of rubber between plies, number of plies or any feature of design affecting flexibility will influence service performance. However, with the possible exception of tread and number of plies, the influence is very small. Determination of the significance of each by measurement makes possible a balanced design which closely approximates the optimum for any desired operating condition.

Consideration of the described tire properties and use of methods of measuring the riding-quality effect should assist in the removal of judgment of this portion of the elastic suspension of the automobile from the vagaries of observers' opinions and place it within the definite scope of engineering. This accomplished, riding comfort, which is the major reason for the existence of tires, can be more fully realized, possibly without conflict with such important factors as cost, appearance and safety.

THE DISCUSSION

CHAIRMAN E. S. MARKS[6]:—Considerable emphasis has been laid by tire engineers upon the load in pounds that a tire can carry, but another factor which is very important as regards the life of the tire is the continuous high speed at which cars are driven.

MAURICE OLLEY[7]:—Does the curve in Fig. 1 showing the relationship between loading and wheel diameter take account of the optimum of inflation pressure for the tire when changing the wheel diameter from, say, a 20-in. to a 17-in. wheel, or is it based on the same inflation pressure for the tire? Also, has Mr. Brown any data on the variation of the damping or hysteresis loop with the diameter of the tire?

R. W. BROWN:—That curve was plotted from the Tire and Rubber Association recommended pressures for the particular tires in question. It takes account of the change in inflation pressure but does not take account of the increase in inflation pressure necessary to enable a tire of the same size to be used with a smaller rim for the same service. If a change is to be made, for instance, from a 20 to an 18-in. rim, the tire should be inflated higher than the standard pressure in the curve to get the same tire performance.

MR. OLLEY:—If one had been using a 6½-in. tire on a 20-in. wheel and the chart shows that a 17-in. wheel

[4] See *Automobiltechnische Zeitschrift*, April 10, 1931, p. 238.

[5] Head of department of psychology, George Washington University, City of Washington.

[6] M.S.A.E.—Chief engineer, H. H. Franklin Mfg. Co., Syracuse.

[7] M.S.A.E.—Engineer, special problems, Cadillac Motor Car Co., Detroit.

requires a 7-in. tire, does that mean that the 7-in. tire should be inflated to the lower recommended pressure?

Damping Effect within Tire Is Negligible

MR. BROWN:—That is right.

Regarding damping, while a very definite hysteresis loop is shown on the curve, where we took the complete loop at high speeds, the damping is so small in comparison with the energy available that the effect is negligible. The damping appears to be largely a function of the properties of the rubber compound between the plies and the individual cords in the tire carcass. In any event, from a practical viewpoint, it is almost infinitesimally small.

MR. OLLEY:—I have had an idea that, in changing from the old woven fabric, high-pressure tire to the new low-pressure cord tire, we have increased tire life at the expense of riding comfort because the damping friction, which used to be valuable to our riding and destructive of the tire, has been eliminated.

MR. BROWN:—I cannot concur in that thought. While the Bureau of Standards work on tires unquestionably brings out quite emphatically the difference in internal friction, even that large difference has a relatively small damping effect. That brings up the point that riding comfort is relatively unimportant compared with serviceability of the tire to operate at high speed and low cost and even with appearance, but it is one of the factors about which we should know something definite. This investigation was made with the hope of providing the automotive engineers with actual-performance charts whereby they could defend their decisions regarding the optimum tire size for each car model.

Rim Width Important to Comfort

K. D. SMITH[8]:—Has any work been done in checking the amount of deflection of a given size of tire on different rim widths? There has been a tendency recently to use wider rims. I should like to know the effect of that on the deflection.

MR. BROWN:—The effect is definitely pronounced. For the sake of uniformity we ran this series of tests with the same rim width, and it gave us a curve which was grotesque. Present practices are surprisingly close to the optimum rim width for riding comfort. A variation of 1 in., either wider or narrower, makes a very appreciable difference. The technique described will, if carried through for your particular condition, definitely answer any question with respect to rim width.

MR. SMITH:—I feel that car engineers do not appreciate the difference that the use of different rim widths makes in riding comfort. It is an important point because today, on some small passenger-cars, for instance, tires of 4.75 nominal section are being used on rims of 3-in. width between flanges, and at the same time some car manufacturers put tires as large as 6.50 on rims that are 2.69 in. between flanges. Use of the right rim width is of extreme interest to the car manufacturer.

MR. BROWN:—The point is extremely well taken, particularly with reference to rims under 3½ in. between flanges. The narrower rims affect very appreciably the curves that I have shown. The desirability of wide rims from a riding-comfort point of view is very definite and appreciable.

CHAIRMAN MARKS:—Making the rims wider adds to the unsprung weight, so we seem to have another compromise problem on our hands.

MR. SMITH:—I think you will find that we have been able to make tires so that lower flanges can be used on the rims to compensate somewhat for the extra width. Moreover, the wider rims give greater stability, particularly in the front wheels.

Parts Played by Air and Tire Structure

B. J. LEMON[9]:—I want to express appreciation of the effort Mr. Brown has made and the success he has attained in fundamental work on riding-qualities as affected by the tire. We know too little about rubber, the importance of which in the automobile makes fundamental research work of great value.

In a tire as used on passenger-cars, the leavening factor as regards riding-quality is the air pressure. Variation of air pressure is much more elastic than is the rubber itself. Differences of riding-qualities can be measured with instruments, and variation in inflation pressure is very important when we remember that the pressure increases with rise in temperature and is checked perhaps once a week.

The carcass plays a rather important part in the flexibility of the tire, as a considerable part of the load is carried by the structure of the casing. The ideal carcass would be a very thin envelope in which the air did all the work, but tires made to carry heavy cars at high speed require that the carcass must be very strong and the beads reasonably stiff to resist all of the road stresses.

Pressure of the tire on the road is greater at the tread center and diminishes appreciably at the edges. Pressure distribution over the contact area is one of the main factors in tread design. Good traction comes from increased road pressure at the edges of the tread and is not necessarily altogether dependent upon the road-contact area. Even distribution of pressure is needed for good traction, and that means considerable pressure on the edge of the tread.

As regards non-skid properties, a broken tread seems not to slip on the road quite as much as an unbroken tread, although some slippage occurs with both types. The coefficient of friction is greater where the surfaces are more nearly at rest; that is, with a non-skid tire. The elements of the broken tread act like the feet of a caterpillar and some movement is taken up in the deflection of the rubber.

Effects of Tendencies in Tires and Tubes

A present tendency is to use rather thick tubes such as puncture-proof tubes. The effect of putting a very thick tube in the casing may be felt in the riding-quality as well as other factors in high-speed car performance. Most of the tire companies have brought out in the last year or two what are called super-tires. These perhaps help to avoid the puncture hazard, but the result has been to require a material decrease in air pressure in those tires to get anything like a comfortable ride.

Some additional research on how to rate the load capacity of tires of different diameter is needed. The

[8] M.S.A.E.—Manager, construction and design department, B. F. Goodrich Co., Akron, Ohio.

[9] M.S.A.E.—Field engineer, tire development division, United States Rubber Co., Detroit.

curves shown by Mr. Brown on the effect of tire size on load capacity are based on the Tire and Rim Association tables, which are based on a number of factors, such as the distance that tires of different diameter roll, the air capacity of the tire, and the impact from road irregularities, which is controlled in some respects by the diameter of the tire.

Noise enters into the question of riding-quality to some extent and is related to tread design. The tendency now is more and more toward rib tread design, because cars are becoming more quiet and noise from tires is unavoidable with a non-skid design. The vibration inside the car, which is transmitted by the snapping of the non-skid design when going over a rough road, is becoming more and more of a problem to the car manufacturers who are trying to design a quiet vehicle.

Upholstery Materials as Sound Deadeners

P. D. PADDOCK[10]:—The possibility of using materials of various kinds inside the car to absorb noise has come up in connection with a research which we have been making. We have employed Dr. William Braid White, director of acoustic research of the American Steel & Wire Co., to conduct the investigation. He has been using a Westinghouse oscillograph, a microphone and an amplifier to pick up the noises produced inside the various types of car upholstered in different kinds of material, and has prepared a report showing that, although the use of upholstery in the car obviously has no effect in making an engine or any part of the chassis quieter, certain materials have marked value over others in reducing the noises inside the car. Dr. F. A. Moss, in his wabblemeter tests[11], found that noises, particularly squeaks and rattles, contribute to fatigue, and Dr. White's tests show that certain materials have a marked effect in absorbing the high frequencies that are most disturbing to the ear.

MERRITT L. FOX[12]:—Mr. Brown mentioned the necessity of getting the period of the tire and the unsprung weight out of synchronism with that of the body.

Another point that has been investigated is that the front and rear tires and unsprung weight have periods that may synchronize with each other as well as with that of the body. One of the most difficult riding-quality problems is to prevent forward and rear pitching on some roads at certain car-speeds. This pitching element is simply a synchronism of front and rear-end body frequencies.

[10] Secretary, Mohair Institute, Chicago.

[11] See S.A.E. JOURNAL, September, 1931, p. 243.

[12] M.S.A.E.—Manager of research, Houde Engineering Corp., Buffalo.

Diesel and Otto-Engine Characteristics

THE DIESEL cycle originally called for combustion at constant pressure, which meant that fuel was being burned during possibly one-tenth of the stroke. Such a cycle does not adapt itself very well to high-speed performance, and it now seems to be the ambition of every Diesel-engine manufacturer to do away with this fundamental requirement of the Diesel cycle and approach combustion at constant volume. This point is of more than academic interest. We hear much about a Diesel-engine performance being more like that of the steam engine and not a series of more or less abrupt power impulses, as is the case in the Otto cycle. If constant-pressure burning is to give way to constant volume, or even approach it, the advantage of this gentle push of the Diesel will have to be forfeited.

Efficiencies of the Diesel cycle and the Otto cycle are identical under the same conditions, but much higher compression ratios are used in the Diesel and for that reason the efficiency is better. The fact that higher compression ratios can be used with the Diesel is of distinct advantage, but it does not account for the entire increase in economy.

Diesel engines, under their so-called full load, are operated with an excess of air varying in percentages from 10 to probably 25. In our automobile engines we generally use an air-to-gasoline mixture of about 12:1. This gives maximum power and the exhaust-gas analysis shows the presence of about 4 per cent of carbon monoxide. We could run the engines on a mixture of 20:1 and greatly improve the full-load economy, but under such conditions the power output is very much reduced. We could make a bigger engine that would give more power and still run very economically, but the weight-to-horsepower ratio would be too large. Therefore we deliberately reduce the economy so as to get more power out of an engine of given size. In the face of this the Diesel-engine manufacturer gets his fuel economy because of a large percentage of excess air. He cannot well help himself, because, unless he runs with a considerable excess air, the exhaust will become smoky and other combustion troubles will result. As soon as he learns how to do it, he will use less excess air and thereby sacrifice some of the economy in favor of higher power output.

The speed range of Diesel engines, as we know them today, is rather limited. In passenger-car practice, our gasoline engines have a range from probably 200 to say 3500 r.p.m., something over 17:1. Even among the conservative motor-truck and motorcoach manufacturers, the speed range from mean to maximum will average from 10 or 12:1. In Diesel-engine practice a speed range of 5 or 6:1 represents the absolute maximum. This certainly will affect general road performance.

One advantage that is inherent in the Diesel engine, and which for some reason is not usually discussed, is its high efficiency at part loads. Most of the bad fuel economy in our automobile engines is occasioned by the part-load performance. This is an inherent disadvantage of the Otto-cycle engine.—Ferdinand Jehle, research engineer, White Motor Co., in discussion at a Cleveland Section meeting.

Body Comfort and Interior Appointments

Semi-Annual Meeting Paper

By H. A. Brunn[1]

TWENTY-FIVE YEARS AGO America's foremost actress said to me, "If it is stylish I will get in on my hands and knees." This remark was made because I told her that a certain design of special body which she desired would be difficult to get in and out of. Since that day I have waited upon hundreds of people and 99 out of 100 desire first to be comfortable.

Do not think I am going to push style into the background, for such is not the case. Experience has proved that it is possible to secure both style and comfort in the same vehicle. After 35 years of experience I have come to the conclusion that the only method to pursue to secure both style and comfort is to first lay out the seating arrangement and then surround it with the outline. I realize that many smart-appearing close-coupled cars are being sold, but I also know that many of these are soon replaced by other cars that are more comfortable. Do not forget that you cannot cut a piece off the passenger. The owner wants to be able to get into his vehicle easily and take all of his anatomy with him, and it is possible that he would like to take some luggage.

Soft cushions and lazy-backs are of little use in an ill-proportioned seat; in fact, I would prefer a hard seat and back of the right proportions to a soft cushion and back that were not properly proportioned. We always begin by laying out the chassis in full size on our blackboard, showing the steering column, pedals and gear-shift levers in their correct positions. A certain distance must be allowed between the steering-wheel and the face of the upholstery, and a certain distance for the springs and hair used to provide the lazy-back. This method locates the panel against which the front-seat back will rest. We have a certain distance that we must allow from the face of the lazy-back to the front edge of the cushion and a certain distance from the floor to the top of the cushion at its front edge. These dimensions may vary somewhat, but not to any great extent.

It seems that it will be only a matter of time when all bodies will be built with adjustable seats, both front and rear. Passengers vary so much in their physical dimensions that to make permanent seats that are comfortable for all is practically impossible. An adjustable seat virtually assures a comfortable seat for either large or small passengers.

Seat Frames, Springs and Stuffing

Another important factor that enters into comfort is the location of the seat frame on which the cushion is to rest. Great care should be exercised to have the seat frame the correct height from the floor, and we should be assured that it has the correct amount of slope. This is especially true regarding the rear-seat frame.

All of the blame for uncomfortable seats must not be placed on the body builder. We often encounter a chassis so constructed that we are confronted with the problem of building a comfortable rear seat over a large dishpan that sometimes projects 2 or 3 in. up into the bottom of the cushion. No matter what cushion springs are used, it is practically impossible to make a comfortable seat over such a pan. For many years we have used an hour-glass type of woven-wire-mattress construction. We have experimented with many other types, but none has given such complete satisfaction; but even this type of spring will fail to give satisfaction unless sufficient height is allowed for the springs. The springs must be made of wire of the right gage and of suitable steel, and the cushion must be made by a competent workman.

We long since discovered that the finest long, curled hair obtainable is the most economical in the long run. To be truly comfortable, a cushion and back must not be too soft; it is one thing to sink into a very soft cushion when the car is standing on the showroom floor, but how do you feel after riding 100 miles without arising?

Very few lazy-backs give support in the right place, which we think is in the hollow of the back. Invariably one can feel the top and border wires used to construct the lazy-back.

Good style breaks down selling resistance, but comfort keeps the car sold. We give as much attention to a chauffeur's seat as we do to the owner's, for no one will put the skids under an automobile more quickly than an uncomfortable chauffeur.

Sound-Insulation

Sound-insulation presents a very difficult problem. The composite body, that is, one having a framework of ash covered with aluminum panels and castings and which has a leather top and leather side-quarters, is less susceptible than the all-steel body to the noises that arise from the chassis. The fabric body is even better in this respect, but has other objectionable features. Bodies made almost entirely of steel, including the floor and seat-pans, magnify all of the sounds coming up from the chassis. In an all-steel body, vibrations of the chassis are magnified many times. If dashes, floors, seat-pans and other body parts are to be made of steel, they should be of heavy material and reinforced to reduce vibration as much as possible. Floors of wood covered with heavily padded carpets help considerably. The best insulation plan is to use a pad between the chassis and the body. It is the responsibility of the chassis engineer to do all in his power to build powerplants having the least possible vibration.

Ventilation can be secured through a combination dome-light and ventilator in the roof, and also by using small glass panels 3 or 4 in. wide on the outside of the upper part of the door frame.

Vanity cases are fast passing out of the picture, I believe. We supply ground-glass mirrors in one side of the arm rest and an ash tray and cigar lighter in the other rest.

We have been using an English Neutralite glass for

[1] M.S.A.E.—President, Brunn & Co., Inc., Buffalo.

outside visors for more than 10 years and have never found anything to take its place. I am not very much in favor of heavy-glass framed visors inside of bodies, because they are very dangerous in case of an accident.

I predict that the automobile of the future will become one unit rather than two. Undoubtedly it will be built as two units, one being the body and the other the chassis, but I am sure that these will be so much in harmony that they will appear as one.

Coach Building Reviving as an Art

For hundreds of years, coach building was regarded in European civilization as one of the highest forms of commercial art. The coach was an outward indication of wealth and aristocracy, and the most skillful artists of the day were engaged in the industry, sometimes spending several years in building a single coach. Often the lines of these coaches were very beautiful. There are coaches in Holland on the panels of which Rembrandt painted pictures. Up to the middle of the 19th century, coach building flourished greatly. Then, with the coming of the steam railroads, modes of travel changed and its decadence began.

Again, only a few years ago, another evolution in transportation occurred with the coming of the automobile. This was in the nature of a direct improvement upon the coach of former days. Manufacturers and owners are now turning their attention more and more to the body of the automobile. The desire for beauty of line and finish and for the expression of one's own taste is causing a revival of coach building in a new form. The buyers, both men and women of today, are just as keen for individuality and distinctive appearance in their automobiles as the old aristocrat was proud of the exclusive features of his family coach. Let us resolve to make an earnest, painstaking effort to do our part toward bringing about a permanent revival of this old art and apply it to modern vehicles.

THE DISCUSSION

PAUL D. PADDOCK[2]:—Mr. Brunn's paper and his viewpoint about riding comfort suggest exactly the property that the automobile user is anxious to get. As engineers, you will see that something is radically wrong with the engineering design of these chairs on which we are sitting. If you can sit erect for a long time without slipping on this material, the grain of which runs forward instead of transversely, you are a better acrobat than I am. Merely turning that cover material crosswise would help you maintain the correct position.

We have recently been making a research into the question of automobile comfort and its relationship to safety and have consulted with two of the greatest experts on that. The best authorities we could find tell us that when a person sits incorrectly he places his own shock-absorber, which is his spine, in a position in which it can least efficiently absorb shocks and jars. The spine is the best shock-absorber ever made. If it is tipped at a wrong angle, as when one sits incorrectly in a car, it cannot function properly and undue fatigue results, causing a great deal of unpleasant muscular and nervous trouble.

This opinion comes through the National Safety Council from Dr. Dudley B. Reed, professor of hygiene and director of physical education of the University of Chicago; Dr. H. E. Bennett, educational director of the American Seating Co.; and other authorities. It is literally true that, because of habitual riding in an improper posture, automobile drivers are inviting accidents besides suffering undue fatigue and nervousness.

Seats To Give Correct Posture

Correct posture simply means that in driving or in sitting in any seat, one should sit with his back well against the back of the seat. As Mr. Brunn suggested, it is highly important to have a support for the back at a point above the hips and below the shoulder blades. The feet should be able to reach the floor and the pedals without stretching or straining. It is also extremely important that there be no pressure under the knees.

Many riders find that the usual automobile seat is too deep; they have to sit too far back to get support for the back. That throws their legs into such a position that there is pressure under the knees. Medical authorities tell us that this is a direct cause of sciatica and other nervous troubles. The weight should rest mainly on the seat bones.

If automobile designers and builders will stress comfort, not as a luxury or just a fad, but as a sane, engineering principle, a constructive idea, they will contribute more than anything else to the safety, the comfort and the well-being of the automobile user.

HERBERT CHASE[3]:—Adjustable seats, which Mr. Brunn mentioned, are being used in a number of cars. I have found that they are rather hard to operate and most of them provide only for horizontal travel of the seat. A short person would like to have the seat rise at the same time that it is moved forward. It should be easy to incline the track instead of having it horizontal. Even when the seat is adjusted forward, I find great difficulty in some cars in reaching the pedals comfortably. If the driver cannot reach the pedals satisfactorily, he does not push the clutch out far enough and so has trouble changing gears.

An easy adjustment of the driver's seat so that a short person can be comfortable in it is most desirable. Also, if the driver is raised somewhat farther above the floor, he will be able to see the road to better advantage. A tall man must put his head almost in his lap to see the usual traffic light when he stops close to it.

One thing in particular that the chassis engineer might do to improve riding-quality, especially in the rear seat, is to abolish the "dishpan" referred to by Mr. Brunn. If we have a big differential in the rear axle, we must have some place for it to go when the wheels strike a substantial bump. One solution of that problem is to eliminate the rear axle and have individual springing of the rear wheels. Such an arrangement should add greatly to riding comfort.

Another possibility is to rearrange the chassis entirely and place the engine in the rear, as advocated in my paper on this subject[4]. Then neither front nor rear seats will come above the axles and they can be built so as to give maximum riding comfort.

[2] Secretary, Mohair Institute, Chicago.
[3] M.S.A.E.—Consulting engineer, Forest Hills, N. Y.
[4] Semi-Annual Meeting paper entitled, Why Not Put the Engine in the Rear.

Simplifying Control of the Automobile[1]

VERY FEW CHANGES have been made in the last 10 to 15 years which have simplified or altered the operations required to drive a car. The tendency has been to add more "gadgets" that increase the confusion of drivers not versed in mechanical matters. But I think I can sense a new activity among engineers and inventors within the last year or so, along with a reawakened demand from the driving public, which is resulting in a rapidly accelerated movement to create simpler control devices requiring less effort and skill on the part of the driver.

Fundamentally, the control of a car consists merely in the control of direction and speed; so it seems that, ultimately, there should be only two operations in the control of the car. The steering-wheel now performs one of these, leaving the starting pedal or switch, the choke, throttle, clutch pedal, gearshift lever and the brake pedal, all of which are necessary today for controlling speed. Some of these may be eliminated by the development of a new drive mechanism or by automatic controls.

Every engineer must be keenly awake to the need of simplifying the control of the car, as otherwise the automobile saturation point may be brought about, not through lack of demand for more automobiles, but through our inability to accommodate them on the street.

Better Steering Control Becoming Necessary

The introduction of balloon tires made it essential to reduce the effort required to steer a car and much has been done in this direction by reducing the friction in all parts of the steering-gear. In reducing the friction it was almost impossible to retain the irreversible gear so popular in the past; consequently, most present-day steering-gears are of the reversible or semi-irreversible type.

If cars and tires continue becoming larger, we shall almost be forced into some remote-control power-operated type of steering mechanism.

The present-day steering-wheel is one of the greatest obstacles to clear vision, as, with the trend toward lower roof lines, high radiators and cowls and low seating position, it is almost impossible to arrive at a location for the steering-wheel that will enable a small person to see without looking through the wheel. I think that the public will not tolerate this condition much longer and that engineers must develop something radically new in steering controls.

Possible Improvements in Speed Control

For safety reasons it seems advisable to retain a separate ignition-switch control, combined with the car lock, although automatic switches have been developed to cut off the ignition in case the driver leaves the car and forgets to turn off the switch. However, the public has preferred the simple manually operated switch for this important control.

Several inventors are now working on choke controls that are fully automatic and that, if successful, will make easy starting and smooth operation of the engine during the warming-up period independent of the skill of the driver.

Many companies are removing the hand throttle from the prominent position it has occupied on the steering column and putting it on the instrument board. Two well-known makes of car have it hooked up with the starter pedal so that it is automatically opened to the starting position when the starting-motor pedal is depressed.

I believe that the foot throttle is destined to remain, but considerable effort has been exerted recently to develop a more comfortable position and easier operation of this control. It is probable that other controls will be combined with the foot throttle. This will be necessary if my prediction of a two-control car is to become a reality; and, in fact, I understand that such a car already has been built in Europe.

Several automatic starting switches which operate the starter when the ignition switch is turned on have been developed and some departures in the form of remote-control switches and finger-tip control have been made. Some automobile manufacturers are now offering them as standard or special equipment. However, I am led to believe that some form of semi-automatic or coincidental operation will be the solution of this control problem.

Prospect for Electric Clutches and Transmissions

Electrodynamic and electromagnetic clutches have the great advantages of being frictionless and very flexible. Recently I talked with an inventor who has had considerable experience with such devices and who claims to have experimentally developed a magnetic clutch that seems to have very good commercial possibilities. The electric or magnetic clutch would greatly simply the control problem. Free-wheeling, which greatly reduces the use of the clutch, deserves a place in the list of clutch-control developments as well as in the gearshift problem.

Probably our greatest hope for an automatic or nearly automatic transmission lies in some development of electric drive or possibly a combination of electric and gear drive. Improvements recently made in transmissions cannot help but awaken the old desire for a fully automatic drive. Several attempts have been made in recent years to develop a mechanical transmismission that would automatically compensate for variation in load and speed requirements; but, like the electric drive, those that have been developed have limitations which more than offset the advantages to be gained from their use.

The great bugbear of the brake engineer is the wear of the friction surfaces. The answer to his need, and also to the problem of a control that can be more quickly and easily operated, would seem to be frictionless brakes. The principle of the magnetic clutch previously mentioned has been applied also to brakes and, if it can be made commercially practical, I foresee better days ahead for the automotive electrical engineer.

If legislative objections could be removed, there is little doubt that the same brakes that are used for service application would be hooked up to a hand lever and used also for parking. Our service brakes would, of course, need to be doubly protected against failure before the following of such a course would be safe.

Cars are driven by persons of differing wealth, mentality and physical stature, most of whom have long forgotten the thrills of tinkering with the car and who are demanding more than mere transportation. They want a car that will take them to places quickly, quietly, safely and with the minimum of mental and physical exertion. I have great faith in the ability of our engineers to fulfill this demand.

[1] From a Canadian Section paper by P. J. Kent, M.S.A.E., chief electrical engineer, Chrysler Corp., Detroit.

Further Investigation of Fuel Injection in an Engine Having Spark Ignition

20th National Aeronautic Meeting Paper

By E. S. Taylor[1] and G. L. Williams[2]

THIS INVESTIGATION of fuel injection with spark ignition is a continuation of work previously reported,[3] which was carried on in the aeronautic-engine laboratory of the Massachusetts Institute of Technology. Although a four-cycle engine was used, the fuel was injected during the compression stroke so that the results might be applicable to the two-stroke cycle without possibility of loss of fuel through the exhaust.

Among the effects studied were those of stratification and of late injection or late ignition as a means of controlling detonation with high compression. Fuels used were aviation gasoline, ordinary Diesel fuel and hydrogenated fuel oil, the last seeming to offer interesting possibilities. Directed turbulence was found to be essential for good distribution of the fuel in the cylinder and satisfactory operation of the engine.

Discussers questioned as to lubrication difficulties in the injection pump and valve and the engine cylinder, the possible availability of hydrogenated fuel oil and the theory of combustion under the test conditions. A contribution was made as to the action and effect of turbulence.

APPARATUS used for this investigation included a 3¼ x 4½-in. Cooperative-Fuel-Research engine, together with an electric cradle-type dynamometer, such other equipment as was required for a complete performance test, and such special equipment as was necessary for this particular investigation. The fuel flow was computed from the time required to use the known volume contained in the fuel meter. The air flow was measured by means of a round-edged orifice, a 10-gal. drum and restriction being interposed between the orifice meter and the engine to reduce pulsations. The arrangement of the set-up is shown in Fig. 1. A complete description of the engine, with drawings of the longitudinal and transverse sections, has been given in a paper by H. L. Horning[4].

A Bosch cam-operated plunger-type fuel-pump was used for injection, driven through a planetary-gear drive which permitted easy adjustment of the injection timing to any desired position between top center at the beginning of the suction stroke and top center at the end of the compression stroke while the engine was in operation. The planetary gear was driven by a roller chain from the engine. The pump and drive can be seen in the foreground of Fig. 2. The duration of injection for this investigation varied from 19 to 25 deg. of crankshaft rotation, according to the desired mixture ratio.

The injection valve used is of a type developed especially for this investigation. The original valve of this type, described in the report on the application of fuel injection to four-cycle engines[3], was modified somewhat to fit the engine and to meet the requirements of the late injection that is necessary with two-cycle engines. Fig. 3 shows the modified valve used for these tests, together with the original valve. Diaphragm springs were used in the later valve, instead of coil springs, to make the valve more compact. With late injection, some trouble was experienced from alteration of the shape of the spray because of the deposition of carbon on the valve. Cutting away the face of the hollow cone to leave only a narrow edge upon which the fuel impinges alleviated this difficulty. The opening pressure of the valve was set at about 3,000 lb. per sq. in. In other respects, the valve is similar to the original valve.

The position of the spray with respect to the combustion chamber is shown in Fig. 4. Tests with various shapes of spray showed this arrangement to give the best performance. The fact that the axis of the

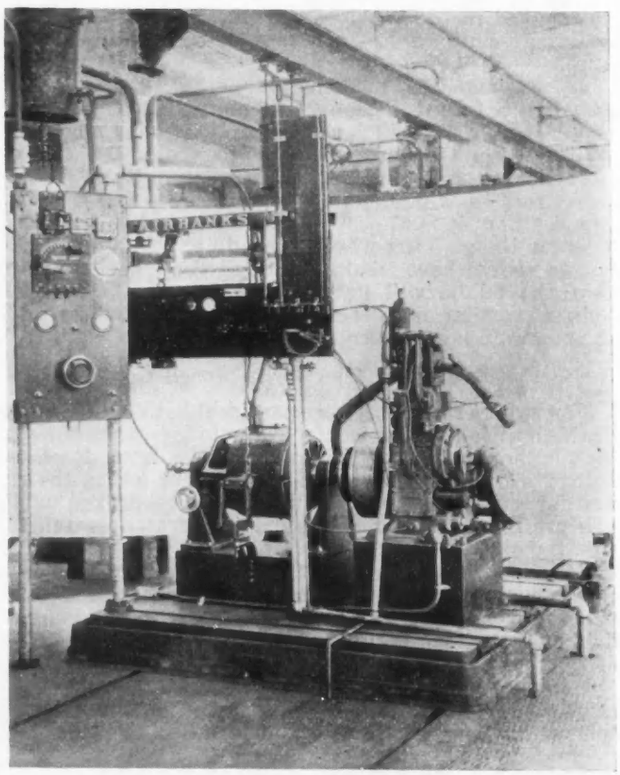


FIG. 1—ENGINE AND DYNAMOMETER USED IN TESTS

[1] Assistant professor of aeronautical engineering, Massachusetts Institute of Technology, Cambridge, Mass.

[2] Research associate, Massachusetts Institute of Technology, Cambridge, Mass.

[3] See S.A.E. JOURNAL, March, 1931, p. 345.

[4] See S.A.E. JOURNAL, June, 1931, p. 637.

spray cone makes an angle of 45 deg. with the cylinder axis, while the axis of the hole through which the injection valve is inserted is at 30 deg. from the cylinder axis, was the principal reason for modification of the spring-loaded injection valve to a more compact design.

Steady Operation Requires Directed Turbulence

Erratic operation with late injection made it evident at the beginning of the investigation that the distribution of mixture in the combustion space was poor at the time of the passage of the spark. In order to determine whether the spark-plug was in an unfavorable position, a plug was made up with extended points so that the spark gap could be placed at various points in the combustion space. The results of this test showed that, without directed turbulence, the distribution of the fuel is very poor and operation is uncertain regardless of the position of the spark-plug. The shrouded inlet valve shown in Fig. 5 was designed to cause rotary turbulence in the combustion space.

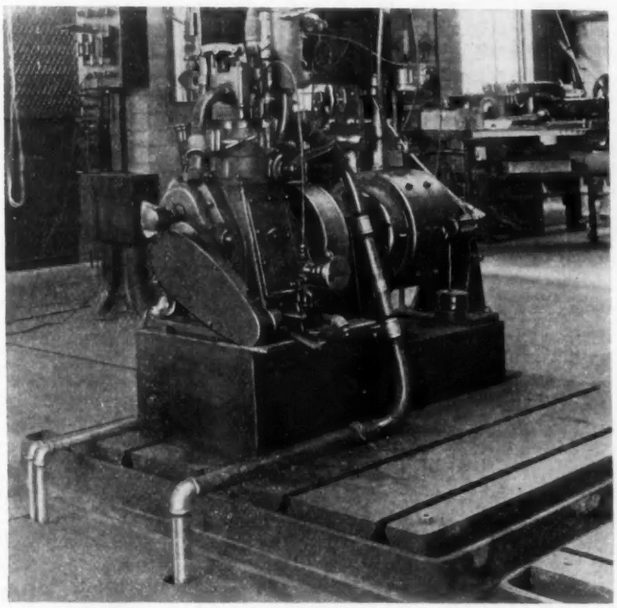
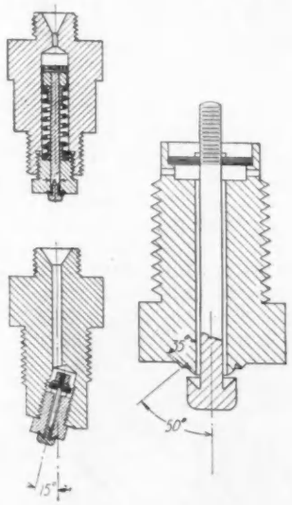


FIG. 2—CLOSE-UP OF ENGINE, SHOWING INJECTION PUMP



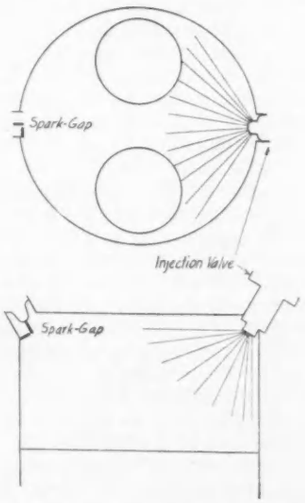


FIG. 3—INJECTION VALVES USED IN TESTS

FIG. 4—DIAGRAM OF COMBUSTION CHAMBER OF TEST ENGINE

At the Left Are Shown (Above) The Spring-Loaded Valve Used in the Tests Previously Reported and (Below) the Present Valve in the Adapter Which Gives It the Correct Angle in the Cylinder. Details of the Newer Valve, with Its Diaphragm Spring, Are Seen in the View at the Right

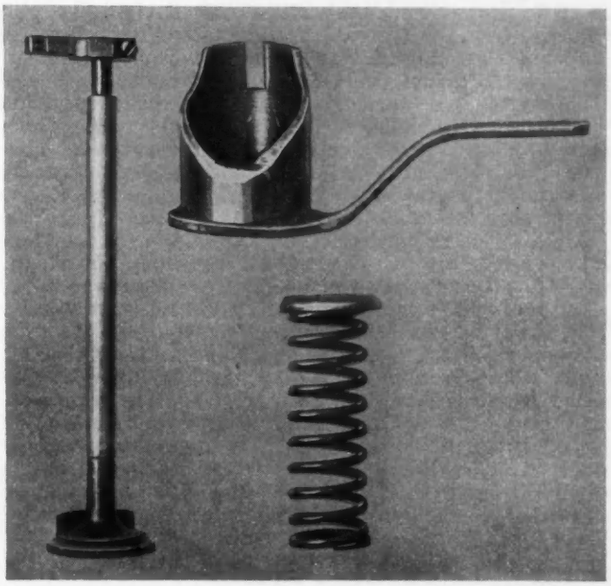


FIG. 5—SHROUDED INLET VALVE, WITH LEVER FOR ADJUSTING ITS POSITION

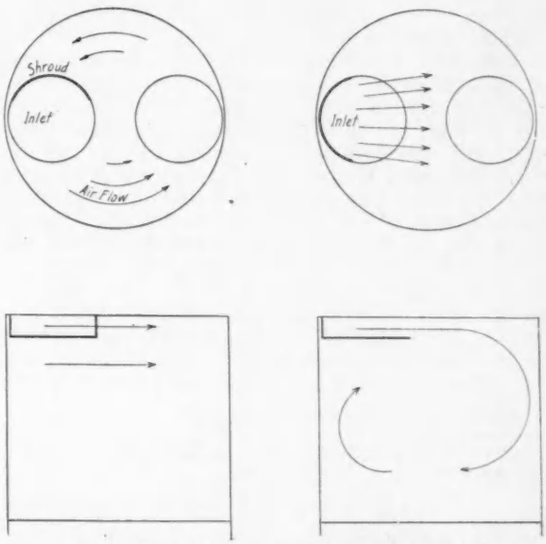


FIG. 6—DIAGRAM SHOWING PROBABLE TURBULENCE WITH THE VALVE SHROUD AT ITS EXTREME POSITIONS

The valve assembly was set up in such a way that the position of the shroud might be varied through a range of 90 deg. simply by movement of a lever on top of the engine. The extreme positions of the shroud and the probable turbulent effect in each case are shown in Fig. 6. The direction of the air flow with intermediate positions of the shroud is not readily apparent, but some combination of the motions indicated in Fig. 6 probably would result.

Tests with various positions of the shroud on the inlet

valve indicated that the most consistent results were obtained with the shroud placed so as to give full rotary turbulence as indicated at the left in Fig. 6, although better performance could be obtained under some conditions with the shroud in an intermediate position. With rotary turbulence, the fuel seems to be fairly well distributed throughout the combustion space; however, the lean limits of operation indicated that the mixture at the top near the spark-plug is richer than the mixture at the bottom near the piston.

All tests were made at full throttle, with the load adjusted to maintain a constant speed of 1000 r.p.m., except for the throttling tests which are discussed in the latter part of the paper. The injection timing was varied from about bottom center at the beginning of the compression stroke to as late as was consistent with steady firing. At each injection timing, the mixture ratio was varied from the lean limit to very rich. The tests were made at a compression ratio of 5:1, except in tests of the effect of injection timing on detonation, during which the ratio was varied, and tests with fuel oil, in which the ratio was 4:1. The shrouded valve was in place and set to give maximum rotary turbulence for all tests recorded in this paper.

Gasoline Injection

The first series of tests was made with aviation gasoline, the distillation curve of which is shown in Fig. 7. The timing of the beginning of injection was varied from 30 deg. before bottom center to 90 deg. after bottom center on the compression stroke.

As a summary of this survey, the best performance as to fuel-air ratio, brake mean effective pressure and specific fuel consumption are plotted against injection timing in Fig. 8. It will be noted that the curves obtained with the low-penetration valve are irregular. This irregularity, which was verified by a number of tests, is probably due to the fact that the air from the unshrouded side of the inlet valve sweeps directly across the injection valve, cleaning away the spray as it comes from the valve and thus stratifying the fuel into the upper part of the combustion space. The inlet valve closes at about 30 deg. after bottom center; and, the stream of very high-velocity air from the inlet valve being stopped, the penetration of the spray increases, giving better distribution of the fuel through the combustion space and increased power. The minimum fuel consumption seems little affected in this range, the decrease in mechanical efficiency due to decreased power apparently being balanced by increased thermal efficiency due to stratification. However, the increasing pressure and temperature in the combustion chamber after the closing of the inlet valve, resulting from compression, and the decreasing interval of time before the spark passes apparently bring about poorer distribution of the fuel and a corresponding decrease in performance.

A plain 45-deg. poppet-type injection valve with greater penetration and poorer atomization was tried over the same range of injection timings and, as Fig. 8 shows, the engine was found to be much less sensitive to the stratification effects. The best results obtained with early injection into the inlet pipe are represented by the horizontal lines, for comparison with the performance obtained in these tests. Previous work has shown 5 to 7 per cent more power and 6 to 11 per cent lower minimum specific fuel consumption with this method than can be obtained with a carbureter.

The results indicate that, for best performance, injection should begin about simultaneously with the closing of the inlet valve and that the performance obtained under these conditions is excellent.

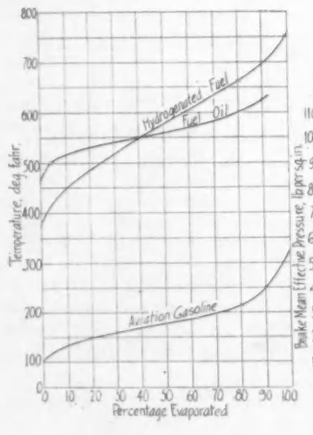


FIG. 7—DISTILLATION CURVES OF THE FUELS USED

The Hydrogenated Fuel Is a Special Aviation Diesel Fuel Made by the Standard Oil Co. of New Jersey

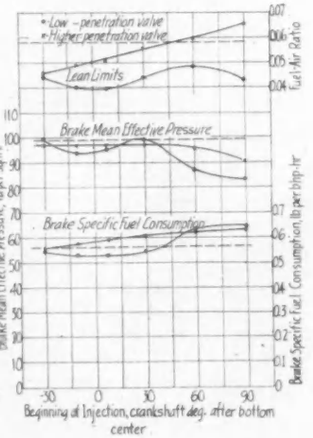

Low-penetration valve
Higher penetration valve
Lean Limits
Brake Mean Effective Pressure
Brake Specific Fuel Consumption
Fuel-Air Ratio
Brake Mean Effective Pressure, lb per sq in.
Brake Specific Fuel Consumption, lb per bhp-hr
Beginning of Injection, crankshaft deg. after bottom center

FIG. 8—EFFECT OF INJECTION TIMING UPON PERFORMANCE WITH AVIATION GASOLINE

Engine Speed, 1000 R.P.M.; Compression Ratio, 5:1; Spark Timed for Best Power

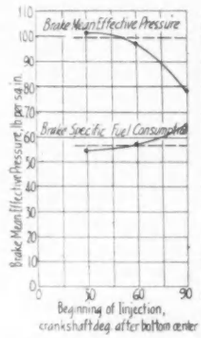
Injection of Heavier Fuels

Attention was next turned to the possibility of using heavier fuels for injection in two-cycle engines. The heavier fuels produced by the hydrogenation process offered a very interesting field for investigation because of their high antiknock value, and a special hydrogenated aviation Diesel fuel of low volatility, supplied by courtesy of the aviation department of the Standard Oil Co. of N. J., was tried. The distillation curve for this fuel also is shown in Fig. 7.

The curves of best performance against injection timing for this fuel are shown in Fig. 9. As may be seen, the results are very similar to those obtained with aviation gasoline, and the performance is even slightly better with injection beginning at the closing of the inlet valve.

An ordinary low-grade fuel oil, the distillation curve of which is given in Fig. 7, was used in a series of tests in which the compression ratio was reduced to 4:1 to avoid detonation. Surprisingly enough, it developed that the range of injection timing possible with this heavy fuel is wider than with aviation gasoline. Performance plotted against injection timing for these tests is shown in Fig. 10. It will be noted that, while best power is obtained with the earlier injection, the fuel economy rapidly improves as the injection becomes later, and it appears that injection should be as late as possible for minimum fuel consumption with fuel oil. Furthermore, it was found possible, even at this low compression ratio, to inject as late as 110 deg. after bottom center with steady firing, whereas gasoline could not be injected later than 90 deg. after bottom center without missing. In later tests with higher compression ratios, this heavy fuel oil was injected, beginning as late as 40 deg. before top center, with steady firing and fuel economy approaching the best that could be obtained with gasoline. With this timing, injection is scarcely complete when the spark passes. This offers some food for thought to those who insist that the fuel must be vaporized before ignition.

It was found possible, with injection of the fuel beginning 100 deg. after bottom center, to use fuel oil at a compression ratio of 5:1 without detonation. The performance obtained with fuel oil at this compression ratio and injection timing can be compared in Fig. 11 with the performance obtained with gasoline and hydrogenated fuel at the same compression ratio but with in-


Brake Mean Effective Pressure
Brake Specific Fuel Consumption
Brake Mean Effective Pressure, lb per sq in
Beginning of Injection, crankshaft deg. after bottom center

EFFECT OF INJECTION TIMING UPON PERFORMANCE WITH OIL FUEL

Engine Speed, 1000 R.P.M.; Compression Ratio, 5:1; Spark Timed for Best Power

Fig. 9—With Hydrogenated Fuel

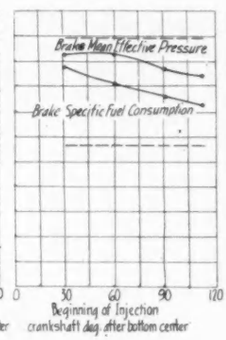
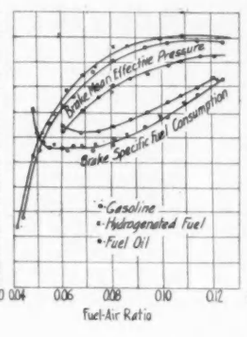

Brake Mean Effective Pressure
Brake Specific Fuel Consumption
Beginning of Injection crankshaft deg. after bottom center

Fig. 10—With Ordinary Fuel Oil



PERFORMANCE CURVES FROM VARIOUS TESTS

Engine Speed, 1000 R.P.M.; Compression Ratio, 5:1; Spark Timed for Best Power

Fig. 11 — Curves for Gasoline and Hydrogenated Fuel Injected Beginning 30 Deg. after Bottom Center and Fuel Oil Beginning 110 Deg. after Bottom Center

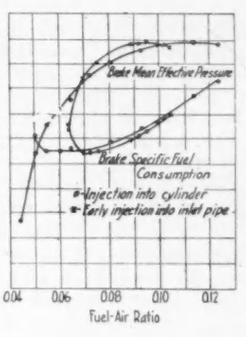


Fig. 12 — Curves for Injection into Cylinder and Early Injection into Inlet Pipe

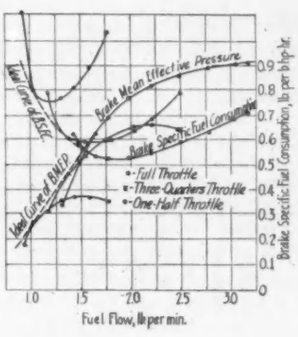

Brake Mean Effective Pressure
Brake Specific Fuel Consumption
Full Throttle
Three-Quarters Throttle
One-Half Throttle
Fuel Flow, lb per min.
Brake Specific Fuel Consumption, lb per b hp hr

Fig. 13 — Illustrating Flexibility of Mixture Ratio at Various Throttle Settings

jection beginning 30 deg. after bottom center. Because of the much later injection, the power obtained with fuel oil is considerably less than that obtained with the other fuels.

This brief survey suggests a most important field for the application of injection systems for use of the heavier fuels, especially the hydrogenated fuels, to both two-cycle and four-cycle engines without sacrifice of fuel economy, perhaps even with better fuel economy than is obtainable with gasoline in the conventional engine of today.

Results with Stratification

Performance curves typical of those obtained with late injection into the cylinder are plotted in Fig. 12 for comparison with curves obtained with injection into the inlet pipe. It is apparent that the characteristic shape of the curves of brake mean effective pressure and brake specific fuel consumption versus mixture ratio are considerably modified with late injection. These variations from the usual shape apparently indicate that there must be stratification of the charge. Obviously, if the spark-plug is surrounded by a combustible mixture, the engine will fire steadily regardless of the mixture in the rest of the cylinder. Therefore steady operation may be obtained if the spark-plug is in the region of good mixture, although the apparent or average mixture in the cylinder is much too lean to burn. Moreover, if the mixture is unevenly distributed it will be necessary to have some portions of the combustion space overrich in order to assure full utilization of the air in the portions having leaner mixture. As a result, the mixture corresponding to maximum power is somewhat richer than normal.

A characteristic of the diaphragm-loaded injection valve used in these tests is that the penetration decreases very rapidly as the quantity of fuel injected decreases. This fact, together with the inherent tendency toward incomplete distribution with late injection and the turbulent action of the air, apparently causes stratification of the fuel into the upper portion of the combustion chamber, especially at lean average mixtures. As noted in the foregoing, the fact that best power occurs at an unusually rich mixture indicates that there must be some stratification at rich mixtures, and the stratification becomes more pronounced as the quantity of fuel injected is decreased and the average mixture in the cylinder becomes leaner.

Normally, as the fuel-air ratio is decreased, a point is reached beyond which burning is too slow to give efficient operation and there is the characteristic rapid decrease in power and a sharp rise in brake specific fuel consumption. However, as the fuel-air ratio is decreased with stratification, a combustible mixture is retained at the spark-plug although the average mixture in the cylinder may be well below the lean limit. That is, the explosion is more or less confined to the upper part of the combustion space and the layer of excess air at the bottom acts for the instant as part of the combustion-space wall. As a result of the increasing degree of stratification with decreased quantity of fuel injected, the effect is as though the displacement of the engine were gradually decreased, and the power accordingly gradually decreases although the average mixture in the cylinder may apparently be too lean to burn.

Stratification Improves Low-Throttle Efficiency

The maximum theoretical thermal efficiency that can be obtained in an internal-combustion engine is represented by the air-cycle efficiency, in which the working medium is pure, dry air. In the actual engine, however, the working medium is not air but a mixture of nitrogen and combustion products; and certain losses—such as variation of specific heat, dissociation, and heat loss to the cylinder walls—materially decrease the thermal efficiency. Tizard and Pye[5] have shown that these losses depend directly upon the flame temperature, which in turn depends upon the proportion of fuel in the mixture, provided that the fuel-air ratio is less than chemically perfect so that there is an excess of air. Therefore, if the proportion of fuel is reduced, the flame temperature and losses will be correspondingly decreased and the thermal efficiency will increase, approaching air-cycle efficiency as the proportion of fuel becomes less and less. Unfortunately, in the usual internal-combustion engine, the necessity for maintaining a sufficiently rapid rate of burning to assure efficient operation limits the useful mixture ratios to a narrow range near the chemically perfect mixture.

Losses arising from slow burning are the chief cause for the characteristic sharp upward turn of the curve of brake specific fuel consumption for the ordinary engine at lean mixtures. With stratification, as explained

[5] See *Automobile Engineer*, February, March and April, 1921.

in the foregoing, a good combustible mixture is retained at the spark-plug and burning of the fuel is sufficiently rapid for efficient operation although the average mixture in the cylinder may be apparently too lean to fire. Because of the presence of an excess of air in the cylinder, the normal flame temperature existing momentarily in the upper part of the combustion space is quickly reduced; heat losses are decreased; the thermal efficiency is correspondingly increased; and, as the degree of stratification is increased and the proportion of fuel in the mixture becomes less, the thermal efficiency approaches that of the air cycle. In Fig. 12 it can be seen that, as the fuel-air ratio is reduced and the degree of stratification increases, the increase in thermal efficiency seems to balance the decrease in mechanical efficiency due to decreased power, and the brake specific fuel consumption remains nearly a constant at best economy over a considerably wider range and at appreciably leaner mixtures than are possible without stratification.

The wide range of best-economy mixtures eliminates the usual necessity for maintaining a very definite fuel-air ratio to have economical operation and suggests that a rather simple interconnection between the air throttle and the fuel-pump control should be sufficient for most services of the engine. The flexibility of mixture ratios at part throttle is illustrated in Fig. 13.

Some valves that were experimented with give sprays of such a shape that most of the fuel was projected across the cylinder and very little downward. In some cases the stratification was so marked that the engine could be idled with steady firing with the air throttle wide open. However, the degree of stratification did not seem to decrease much with such valves as the fuel quantity was increased, and the best power was only a fraction of what it should be. These valves were discarded as being impracticable, at least for this set-up.

Throttling the Two-Cycle Engine

The problem of throttling the two-stroke-cycle engine has always been difficult. The principal reason for this is that at the bottom of the stroke or the beginning of the compression stroke the cylinder must necessarily be full of gas at approximately atmospheric pressure. Whether this gas is air or a mixture of air and exhaust gases depends upon the degree of scavenging or the pressure increment in the inlet pipe. If some exhaust gas is retained in the cylinder, the high temperature may make possible the firing of very lean mixtures and some degree of throttling. The possibility of stratification of the charge, making possible operation at part load or idling by throttling the fuel alone, gives great promise as a solution of this problem.

Effect of Injection Timing on Detonation

Because of the possibilities of using higher compression ratios without detonation with late injection of the fuel, a brief investigation was made in this field. The first series of tests was made with aviation gasoline. With this fuel incipient detonation occurred at a compression ratio of 5.5:1 with injection early, at the beginning of the suction stroke. From this point the compression ratio was increased by one-fourth-unit increments and the injection timing retarded to incipient detonation in each case. The mixture ratio at each condition was varied from the lean limit to very rich to determine the best performance. The compression ratio for incipient detonation and the corresponding best performance are plotted against injection timing in Fig. 14 to represent the results of this investigation. The compression ratio increases along a smooth curve as the injection is retarded. The curve of brake mean effective pressure increases slightly as the compression ratio is increased, reaching the maximum with injection beginning about 30 deg. after bottom center and falling off rapidly as the injection is retarded still further. This is no doubt due to the incomplete distribution or stratification inherent to late injection.

The gain in fuel economy is much more significant. The fuel consumption improves steadily as the compression ratio is increased and the injection is retarded, reaching the minimum when the fuel is injected at about 80 deg. after bottom center. It is significant that at this point the fuel consumption is nearly 20 per cent less than that obtained under the usual operating conditions. Most of this gain in efficiency apparently is due to stratification, since the increase in power with the higher compression ratio is very slight.

It will be noticed that parts of the curves are dashed. In the range of injection timing thus indicated, the operation of the engine was very erratic and missing occurred at all except very rich mixtures, so that no reliable data could be obtained. This effect was only slightly noticeable in previous runs over this range at lower compression ratios, not enough to appreciably disturb the results. Apparently the penetration of the spray is so reduced or the rate of turbulence so damped with the higher compression ratios that a portion of the air does not receive sufficient fuel and, as the air rotates in the combustion space, there must be some range of injection timing at which this portion of very lean mixture is at the spark-plug when the spark passes. The result would be very erratic operation of the engine in this range, as observed in the other tests. Fortunately, the curve is sufficiently definite on either side of this range and the range is small enough so that the curve can be faired in, probably giving a very close approximation of the results that could be obtained if the engine were redesigned to have more spark-plugs or a greater rate of turbulence.

Curves are also plotted showing the possibilities of increasing the compression ratio with late injection, using the hydrogenated fuel and fuel oil described previously in this report.

Performance obtained with retarded injection, as a means of making possible increases in the compression ratio without incurring detonation, is plotted, for comparison, with the performance obtained with retarded spark, in Fig. 15. These data indicate that, as far as power is concerned, the spark-control method is the

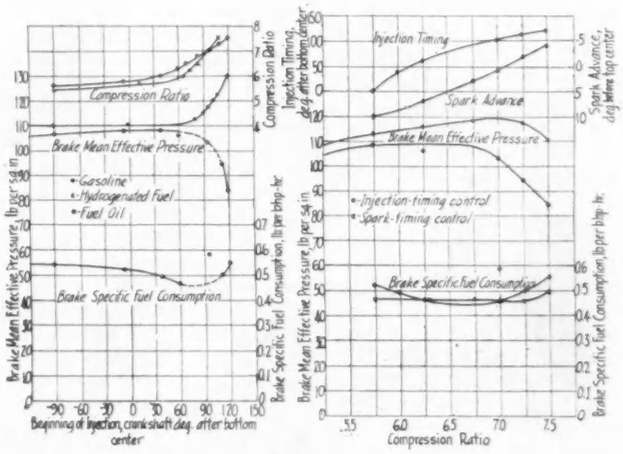

Compression Ratio
Brake Mean Effective Pressure
Gasoline
Hydrogenated Fuel
Fuel Oil
Brake Specific Fuel Consumption
Brake Mean Effective Pressure, lb per sq in
Compression Ratio
Brake Specific Fuel Consumption, lb per bhp-hr
Beginning of Injection, crankshaft deg. after bottom center

FIG. 14—EFFECT OF INJECTION TIMING UPON HIGHEST USEFUL COMPRESSION RATIO AND THE CORRESPONDING BEST PERFORMANCE

Engine Speed, 1000 R.P.M.; Spark Timed for Best Power

Injection Timing
Spark Advance
Brake Mean Effective Pressure
Injection-timing control
Spark-timing control
Brake Specific Fuel Consumption
Brake Mean Effective Pressure, lb per sq in
Injection Timing, deg after bottom center
Spark Advance, deg before top center
Brake Specific Fuel Consumption, lb per bhp-hr
Compression Ratio

FIG. 15—EFFECTS OF INJECTION TIMING AND SPARK TIMING AS MEANS OF PREVENTING DETONATION WHILE INCREASING THE COMPRESSION

Engine Speed, 1000 R.P.M.: Fu[illegible] Aviation Gasoline

better. The difference as to fuel economy is not so marked, and the injection-control method appears to give the better economy over part of the range in spite of the poorer mechanical efficiency.

Summary

From this preliminary investigation of the application of high-pressure fuel injection to two-cycle engines and of the effects upon the combustion process of late injection of the fuel, the following conclusions and indications for future development are suggested:

(1) With injection timings suitable for application to two-cycle engines, that is, injection after the closing of the inlet valve, better power and better fuel economy can be obtained than is possible either with early injection into the inlet pipe or with a conventional carbureter.

(2) Gasoline or hydrogenated fuels of low volatility can be used in this application with equally good performance. The possibility of using hydrogenated fuels of low volatility but high antiknock value is especially promising.

(3) Ordinary low-grade Diesel fuels of low volatility can be used for two-cycle engines with injection, but the performance will be inferior to that obtained with gasoline or hydrogenated fuel. However, there is indication that future development may lead to practical results from such fuels.

(4) It appears from these tests that, with injection later than bottom center, a fair degree of directed turbulence is essential for proper distribution of the fuel through the combustion space and to assure sufficient homogeneity of the charge to obtain good combustion.

(5) Stratification of the charge with late injection is not only possible but to some extent unavoidable. The principal effects of stratification are a considerable increase in the range of useful mixture ratios, a marked improvement in fuel economy at lean mixtures, and a decrease in the maximum available power, all depending upon the degree of stratification and the characteristics of the injection valve.

(6) The highest useful compression ratio can be considerably increased by retarding injection to avoid detonation. However, these preliminary tests show only a slight gain in power as the compression ratio is increased, apparently due to increasing stratification as injection is retarded. It appears that suppressing detonation by retarding the spark offers a distinct advantage in maximum power over detonation control by retarding injection. Remarkable fuel economy, however, can be obtained at the higher compression ratios by suppressing detonation with retarded injection. This possibility of improved fuel economy at part loads, evidently a result of stratification, certainly is worthy of further investigation.

THE DISCUSSION

A MEMBER:—Was any difficulty encountered from scoring in the fuel-pump on account of leakage of lubricant?

G. L. WILLIAMS:—We found in the first investigation that we must have adequate lubrication in the fuel-pump and/or the injection valve or the parts would seize; if we lapped them out enough so that they did not seize, they were so loose that leakage was very bad. In the case of the pump, we found that, if we kept plenty of castor oil in the base around the cam, enough oil would work up around the plunger to prevent trouble.

The first injection valve that we tried lasted about two hours. After spoiling two or three like it, we found that they would not hold up until we eliminated all close fits. That is why we adopted the present type of injection valve.

A MEMBER:—I see that most of the tests were conducted with the injection after bottom center.

MR. WILLIAMS:—We investigated injection during the suction stroke in our earlier work. As we wished this work to apply to two-cycle engines, we felt that it was hardly worth while to investigate any injection timing before bottom center.

A MEMBER:—No injection earlier than say 45 deg. after bottom center can be used in the two-cycle engine.

MR. WILLIAMS:—We realized that injection would need to be at least 30 to 40 deg. after bottom center, but we plotted some of the earlier points to get the direction of the curve at the point at which injection would come.

Vaporization Is Progressive

A. L. BEALL[6]:—What does Mr. Williams mean by hydrogenated fuel? Does he attribute any particular virtue to the hydrogenated fuel over other fuel of equal antiknock value and possibly the same mean volatility?

As a possible theory, in place of his theory of lack of vaporization, I should like to suggest that, when fuel is stratified as he specifies, the combustion begins with a small portion of the fuel that vaporizes as it enters. Vaporization is progressive and carries the combustion on at constant pressure rather than at approximately constant volume. I have never been convinced of fuel having been burned without first being vaporized.

MR. WILLIAMS:—I do not know a great deal about the hydrogenation process, but I do know that the molecular structure of the fuel is attained in some way by its treatment with hydrogen under high pressure. Many reports have shown that the antiknock value of the fuel depends on that molecular structure. Fortunately, the treatment with hydrogen alters the structure so that it approaches that of the best antiknock fuel.

The two fuel oils which we used in this test were of practically the same average volatility. We do not know why the hydrogenated fuel gave good results while the other fuel did not. We know that it is not due to compression ratio; we checked that. One possibility is that the ordinary fuel-oil had 8 per cent of residual gum, which might have caused the difference. Another possibility is the difference in distillation range. While the two fuels had about the same average volatility, the hydrogenated fuel covered a considerably wider range than the other.

We do not maintain that the fuel does not have to be vaporized before it burns; we maintain, from the work that we have done, that it does not have to be vaporized before the spark passes. In other words, the theory of the process, as we see it, is that the spark starts the combustion and it spreads in a more or less spherical form from this spark, and the combustion takes place in the form of a flame front. Quite a distance ahead of this flame front, the fuel is unvaporized, but the fuel is heated up and vaporized right at the flame front as the flame front approaches.

We believe that the vaporization of fuel and the combustion process take place simultaneously. The fact that we can use later injection timing with fuel oil than

[6] M.S.A.E.—Engineer, Vacuum Oil Co., New York City.

with gasoline seems to bear out that point; it is because the ignition temperature of the fuel oil is lower than that of the aviation gasoline. That is the explanation as we see it, but we have no definite data to prove it.

Turbulence and Distribution

A. V. JACKSON[7]:—Two injection nozzles are being used in the cylinders of one of the M. A. N. Diesel engines, one on either side, and the shrouded valve is used for turbulence. The use of two nozzles in future tests might aid in the distribution of the fuel through the air.

MR. WILLIAMS:—We are trying to confine our work to the modification of the single nozzle, avoiding such complications as the use of two nozzles.

MR. JACKSON:—The M. A. N. nozzles run from a single pump. The single orifice in each is 0.011 in. in diameter. The arrangement is such that sprays are thrown into the turbulent air at opposite sides of the cylinder, and it gives very good fuel distribution.

MR. WILLIAMS:—That arrangement requires only one-half revolution of the airstream for the spray to reach the whole of it.

CHARLES O. GUERNSEY[8]:—In the matter of rotary turbulence mentioned by Mr. Williams, a number of tests have recently been made in an effort to measure the rate of swirl induced by inlet valves and passages of various sorts. A dummy cylinder head, containing appropriate ports and valves, was attached to a glass cylinder. Air was then drawn through this combination at various rates of speed simulating various engine speeds. The rotary turbulence was checked by using small windmills inside the glass cylinder, and an additional check was made by measuring the inclination of the spiral marked on the inside of the glass cylinder by appropriate dyes. It was found that a single inlet valve, shrouded as it ordinarily is for the purpose of inducing turbulence, will cause the air to rotate in the cylinder at a speed between two and three times crankshaft speed. By way of illustration, if this rotary speed is 2½ times, one complete rotation of the air would not be completed in less than 144 deg. of crankshaft travel. It is obvious that, if the duration of injection is only 120 deg., the entire volume of the air would not have been carried past the injection nozzle. This would cause a lack of uniformity in the mixture, which accounts for the flat spot or gap to which Mr. Williams refers.

G. FRENCH[9]:—Why was aviation gasoline used in the tests instead of regular motor gasoline?

MR. WILLIAMS:—The principal reason was that we have aviation gasoline in the common fuel system in our laboratory. We could not see that the type of gasoline used would make much difference in the results of our tests except for the difference in antiknock value; the difference in volatility should not matter a great deal.

MR. FRENCH:—Did you notice any difference between fuels in running at full load, say at 1000 r.p.m., and then idling? How did the efficiency of aviation gasoline and fuel oil compare in acceleration?

Low-Grade Fuel Gave Inferior Results

MR. WILLIAMS:—There was no difference between gasoline and the hydrogenated fuel, but there was a great difference in comparison with the low-grade Diesel fuel. A great deal of carbon seemed to be deposited from the low-grade fuel, and much of it went into the crankcase.

MR. FRENCH:—Do you think that there would be more dilution in the crankcase oil at maximum load when using 437-deg.-end-point gasoline than when using fuel oil?

MR. WILLIAMS:—No, I think not, but it is a matter of opinion. The gasoline should not have the gum content which the fuel oil has. Some of the heavier ends of the heavier fuel must have gone into the crankcase; and the gasoline, not having those heavier ends, should not dilute the oil. We had to run a very rich mixture of the fuel oil in some cases to get steady firing, and that probably accounts for the fact that a great deal of the fuel went into the crankcase.

HARRY F. HUF[10]:—The question of using rather heavy fuels in spark-ignition engines has been up for a lot of discussion. Some of us have tried them with equipment of various types. My experience has been that, regardless of how the heavy fuel is introduced into the cylinder, it will eventually cause sticking of the piston-rings if there is any appreciable time between injection and ignition. Was this engine run long enough on either of the heavy fuels to make any observations on that point?

MR. WILLIAMS:—It probably was not. I suppose that neither series of tests lasted more than five days or a week, and that would scarcely be sufficient to have any effect upon the valves. But the fuel consumption with the hydrogenated fuel makes it hard to believe that much of the fuel could be lost around the rings. Fuel that goes down around the rings must come from somewhere, and the waste is shown in the fuel consumption. Since we were getting fuel consumption just as good as with aviation gasoline, we are justified in concluding that the hydrogenated fuel would not cause any more dilution than the aviation gasoline.

However, the fuel consumption was higher with the ordinary fuel oil, and we know that there was dilution of the crankcase oil. It is probable that eventually the rings would have been gummed, if we had run the engine long enough, and we would have had trouble with loss of compression from that cause.

A VISITOR:—What would be the cost of this hydrogenated fuel for great horsepower, assuming that there was a real commercial demand for it? Is there a good supply available, or would the price be excessive?

MR. WILLIAMS:—The cost is several dollars per gallon now, as it is not being used as a commercial fuel and plants are not set up to make such a fuel. When it is made on a production basis, the cost may be less than the cost of gasoline, because the proportion of useful fuel produced from the crude by this method is much greater than that by other methods.

A MEMBER:—What seemed to prevent you from increasing the compression above 6:1? Did the retarded injection leave too little time for combustion?

MR. WILLIAMS:—Throughout the work we encountered stratification, which prevented the fuel from penetrating to the bottom of the combustion space. The penetration was less with higher compression, and that decreased the power.

A MEMBER:—We began similar tests with a Diesel engine as our starting point. If sufficient penetration can be obtained in a Diesel engine, with injection only a few degrees before top center, why cannot the same thing be done with a gasoline engine?

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[8] M.S.A.E.—Chief engineer, J. G. Brill Co., Philadelphia.
[9] A.S.A.E.—Lubricating sales, Sinclair Refining Co., New York City.
[10] Jun.S.A.E.—Senior research chemical engineer, Atlantic Refining Co., Philadelphia.

The Rationalization of Load Factors for Airplanes in Flight

20th National Aeronautic Meeting Paper

By Joseph S. Newell[1]

CONSTANT improvement in airplanes involving increased speeds and increased maneuverability permits of their performing evolutions that were not contemplated when present strength requirements were established. Additional data and experience, however, make possible the breaking down of some of the problems involved into components that can be treated rationally and others that must still be handled empirically. A method for determining load factors in the high-angle-of-attack condition by the use of two rational variables and one empirical coefficient is described and applied to some 19 airplanes, the results being compared with the factors established by current practice. An effort is also made to coordinate wing and tail-loading conditions by establishing limiting velocities for various maneuvers, these depending on the magnitudes of such factors as have been established by experience, the factors being dependent on velocities where new conditions require diving and pulling out from dives at speeds in excess of those formerly considered necessary.

All limitations established must be based on experience and good judgment, hence empirical or approximate procedures can frequently be substituted for more tedious theoretical processes. Because of the empiricism involved in certain factors and the lack of data concerning variables affecting others, complete rationalization of load factors and design conditions is not yet possible, although a number of steps can be taken to advance the art in that direction.

Remarkable unanimity of opinion is expressed by the various discussers regarding the need for rationalizing the load factor, but there agreement ceases. One discusser suggests two formulas including an arbitrary factor of safety multiplied by the speed range squared and multiplying the cube root of the wing-loading:power-loading ratio by a constant respectively. Physiological resistance of the pilot and the strength of the airplane are stressed by another. A third considers that linking the nose-dive and tail-loading conditions with the angle of attack offers the best solution of the problem and points out that the safe pull-out speed should be determined and posted in the cockpit for the pilot's guidance. Piloting technique, more than any other influence, says another, determines the load factor in a given functional group.

THE severest loads imposed on an airplane in flight have long been recognized as those accompanying the maneuvers of going into a dive from level flight by an abrupt push-down and of permitting the machine to remain in the dive until it has reached terminal velocity and then pulling out abruptly. Engineers have designed for four attitudes connected with these maneuvers, the inverted-flight condition being that at the push-down when the load acts downward on the wings, that is, in a direction opposite to that in normal flight; the nose-dive or terminal-dive conditions representing flight at terminal velocity with the wings practically at the angle of zero lift; the low-angle-of-attack condition representing conditions during a pull-out at high speed and small angles of attack, giving a center of pressure well back on the normal wing; and the high-angle-of-attack condition representing conditions later in the maneuver when the angle of maximum lift is reached and the center of pressure is well forward.

The total air-loads acting on the airplane in such maneuvers may be equal to, but are generally greatly in excess of, the loads acting in normal level-flight when the wings are at the angle of attack corresponding to one of these design attitudes. Designers provide for such excess loads by using load factors or quantities by which the weight of the airplane is multiplied before the structural elements are proportioned. The load factors normally used are arbitrary and are based on the results of experience. They normally represent the product of two factors, one being the dynamic factor or applied load-factor that is actually expected to come on the structure at some time during its career and the other being the factor of safety that is introduced to take care of uncertainties in the actual load-distributions, variations in materials and in workmanship and similar items. Experience dictates the minimum factor of safety as 1.5, with 2.0 being far more desirable. Experience likewise shows that actual applied factors conform to those theoretically possible within the normal working-range. The maximum theoretical factors, however, are far in excess of the possibilities for successful airplanes, if success be rated in terms of load-carrying ability, since their use would result in excessively heavy structural elements.

Load Factors at High Angles of Attack

Load factors depend on two characteristics of an airplane, its speed range and its ability to maneuver. Since the loads on the wings of an airplane as it is maneuvered from one attitude to another depend on the lift coefficient at a given angle of attack and the square of the velocity at which the maneuver is made, any change in the lift coefficient due to a sudden change in attitude, or to a change in flying speed, is evidently of the utmost importance in determining the loads that the structure must carry. The greatest velocities normally occur when an airplane is dived. The greatest lift-coefficients are developed when the wings are at a high angle of attack. Hence, the maximum possible loads on an airplane would be expected when it was flown at the high-angle-of-attack attitude and at terminal driving-speed, a condition that can be obtained only in an abrupt pull-up from a dive.

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That a pull-out would be accompanied by a reduction in flying speed due to the drag of the wings at the higher angles of attack and therefore that load factors less than those theoretically possible would be found has been assumed for a long time. Fig. 1, based on data of R. V. Rhode[2], shows how the observed velocities on the PW-9 airplane varied as the normal force-coefficient C_n, which is essentially the same as the lift coefficient for present purposes, varied from that at high speed to the maximum obtained in the high-angle attitude. A decrease of some 10 per cent from the initial velocity is shown.

Rhode has pointed out[3] that full-flight normal force-coefficients are greater than those obtained on a model, probably due to the positive pitching of the airplane. The increase in this particular case was about 26 per cent. Since the load depends on C_n and V^2, a 26 per cent increase in C_n more than offsets the 19 per cent decrease due to a 10 per cent reduction in V in this case. Hence, we are forced to conclude that obtaining the high factors which theory indicates are attainable is possible. Fig. 2 shows how observed factors compared with the theoretical for various pull-outs on the PW-9 airplane.

Let us now see what factors are possible on this airplane, assuming first that level flight is maintained at various angles of attack and that the airplane is suddenly pulled up from these attitudes to that at which the lift coefficient K_y is the maximum. Then let us see what factors are attainable when the airplane pulls out of a dive and passes through various angles of attack without loss of speed. In view of the slight loss in speed shown in Fig. 1 and the compensating increase in lift coefficient, both maneuvers are assumed to be executed without any change in speed. Moreover, since the pressure studies on the PW-9 fuselage indicated that not more than 3 or 4 per cent of the lift on the airplane was developed by the fuselage[4], assuming that all lift acts on the wings seems logical. The lift is computed from the airfoil data, the tail load determined from data of Roché[5] and the net lifting-force in the airplane is obtained. Expressing this in terms of the gross weight gives the theoretical applied load-factors shown in Fig. 3.

Theoretical factors for the high-angle-of-attack condition are slightly more than 24, and applying a factor of safety of only 1.5 gives a design load-factor of 36. While this might be desirable from the viewpoint of attaining perfect safety during any pull-out, its use would so increase structural weight as to render an airplane useless for carrying military load or commercial payload. Other considerations also must limit the design load-factor.

[2] See Report No. 364 of the National Advisory Committee for Aeronautics entitled Pressure Distribution over the Wings and Tail Surfaces of a PW-9 Airplane in Flight, by R. V. Rhode.

[3] See National Advisory Committee for Aeronautics Report No. 364, p. 52.

[4] See Report No. 380 of the National Advisory Committee for Aeronautics entitled Pressure Distribution over the Fuselage of a PW-9 Pursuit Airplane in Flight, by R. V. Rhode and E. E. Lundquist.

[5] See Air Corps Information Circular No. 650 entitled Proposed Method of Determining Design Tail Loads for Airplanes, by J. A. Roché.

[6] See National Advisory Committee for Aeronautics Report No. 307 entitled Pressure Distribution over the Horizontal and Vertical Tail Surfaces of the F6C-4 Pursuit Airplane in Violent Maneuvers, by R. V. Rhode, p. 16.

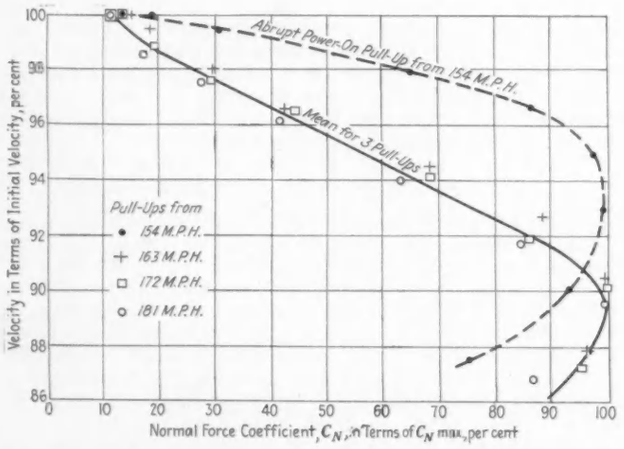
Abrupt Power-On Pull-Up from 154 M.P.H.
Mean for 3 Pull-Ups
Pull-Ups from
154 M.P.H.
163 M.P.H.
172 M.P.H.
181 M.P.H.
Velocity in Terms of Initial Velocity, per cent
Normal Force Coefficient, C_N, in Terms of C_N max., per cent

FIG. 1—CURVES SHOWING CHANGE IN VELOCITY WITH CHANGE IN NORMAL FORCE-COEFFICIENT FOR ABRUPT POWER-ON PULL-UPS FROM NORMAL FLIGHT

These Are for a PW-9 Airplane and Are Based on Data Contained in Report No. 364 of the National Advisory Committee for Aeronautics

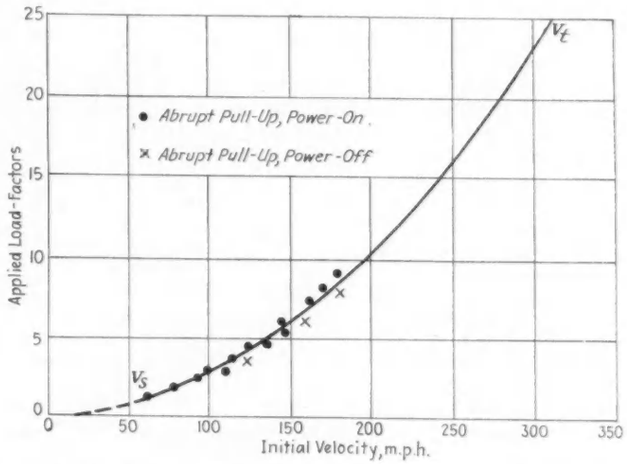

FIG. 2—LOAD FACTORS PLOTTED AGAINST VELOCITY FOR THE PW-9 AIRPLANE

This Chart Indicates How the Observed Factors Compared with the Theoretical for Various Pull-Outs

For military ships the limit may be the ability of the airplane to make an abrupt pull-out at high speed without squashing or it may depend on the physical resistance of the pilot. In making an abrupt pull-up the pilot usually pulls the stick back hard and the elevators, being proportioned to facilitate rapid maneuvering, generally are adequate to hold the airplane at an attitude beyond that of maximum lift with the result that it squashes and the actual load falls off. So far as I know, no accelerometer data are available to provide information as to maximum loads attainable in a squash pull-up. If they are not in excess of those which a pilot can withstand, the magnitude of such loads should be determined, as they represent the true maximum load-factors attainable in pull-outs from dives.

Physical Limitations of the Pilots

Some data on the physical limits of pilots are available but more should be obtained. Rhode states[6] that instantaneous accelerations as high as 7.8g cause the pilot no discomfort although accelerations of the order of 4.5g, if continued for any length of time, result in a complete loss of faculties. Instantaneous accelerations up to 9g have been found to cause no considerable physical reactions but an acceleration of 10.5g, resulting from a sharp pull-out at 173 m.p.h. in the F6C-4, produced marked physical disturbances in the pilot, requiring about a month for his complete recovery. Different pilots would be expected to have different physical

resistances to instantaneous accelerations. Hence, the figure 10.5g, which is based on a single case, cannot be accepted as the absolute maximum for use in design. It might be used as a tentative standard pending further tests and, if such were the case, 16 might be used as a design load-factor for the high-angle condition since it would provide about 50 per cent margin for material and other unknowns.

Assuming an airplane having the characteristics of the PW-9 to have been designed for a factor of 16 so that the limiting applied-factor would be $16/1.5 = 10.67$, we find from Fig. 3 that such a factor would be encountered in an abrupt pull-up from steady flight at —3.5 deg. to the angle of $K_{y\ max}$. Steady flight at —3.5 deg. would occur at a velocity around 210 m.p.h., by interpolation of the computed velocities given by Roché[7], or about 1.25 times the maximum speed in level flight, 166 m.p.h. for this airplane.

Fig. 3 also shows that pulling out from a terminal dive at —4.75 deg. to an angle of attack of about +2 deg. without exceeding the limiting applied-factor of 10.67 would be possible. This would permit a slow pull-out from a terminal dive to an angle at which level flight could be maintained or even some climb accomplished. It would not permit sudden pull-out to high angles of attack and might not be satisfactory for diving bombing airplanes if the pilot were to be permitted to exceed the physical limit during the pull-out, which would require extensive accelerometer tests to determine its value for various pilots. However, the use of a maximum speed for abrupt pull-outs to high-angle-of-attack attitudes and the use of a maximum-angle attitude for pull-outs from dives approaching terminal velocities appear both possible and reasonable limits to set up for pilots operating high-speed, highly maneuverable airplanes, particularly of the pursuit type.

Limitations depending on physical factors might well be established for commercial airplanes of stuntable types, although probably they would be too conservative for the normal requirements of such airplanes and hence would penalize manufacturers unduly. The best that can be done with commercial airplanes appears to be to base factors on the results of experience so far as maximum values go, modifying them where necessary to obtain close accord with recent advances in knowledge and information.

Development of Maximum Load-Factors

Two factors are involved in the development of maximum load-factors, one being the velocity at which the maneuver is executed and the other the rapidity with which the airplane changes attitude while performing the maneuver. The maximum velocity at which a given maneuver can be performed is a function of the over-all cleanliness and design of the airplane, a function that is also involved in what may be called the normal speed-range. This may be defined as V_l/V_s, the maximum speed in level flight divided by the stalling speed. Using this speed range as a factor in the determination of design load-factors appears rational since it represents over-all efficiency in a design. The maneuverability factor representing the rapidity with which changes in angle of attack can be made depends to a considerable extent upon the size of the tail surfaces and their distance from the center of gravity of the airplane or, in other words, upon the moment they can create about the center of gravity. The mass moment of inertia of the airplane about a transverse axis through the center of gravity would, of course, have some effect on the rapidity of angular rotation of the airplane for a given control moment; and a number of other factors, such as damping, further complicate the problem. Neglecting

[7] See Air Corps Information Circular No. 650 entitled Proposed Method of Determining Design Tail Loads for Airplanes, by J. A. Roché.

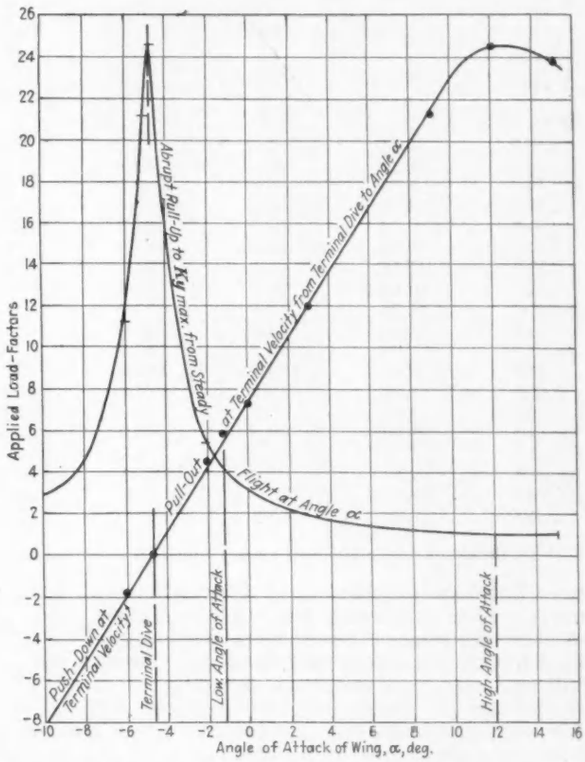
Applied Load-Factors
Angle of Attack of Wing, α, deg.
Abrupt Pull-Up to Ky max. from Steady
at Terminal Velocity from Terminal Dive to Angle α
Pull-Out
Flight at Angle α
Push-Down at Terminal Velocity
Terminal Dive
Low Angle of Attack
High Angle of Attack

FIG. 3—VARIATION IN APPLIED LOAD-FACTORS FOR THE PW-9 AIRPLANE

these and considering only the moment phase of the tail surfaces, we can establish a set of load factors that are comparable to those now used by the Department of Commerce for the high-angle-of-attack condition.

The proposed factors depend on $(V_l/V_s)^2$ and on a control-surface constant that is the area of the horizontal tail-surfaces, expressed as a percentage of the wing area, multiplied by the distance between the center of gravity of the airplane and the center of pressure of the tail surface and divided by the mean aerodynamic-chord of the wings. The factors, as computed for 19 airplanes, are shown in Table 1 and compared with the present factors used by the Department of Commerce. The airplanes used are Army or Navy ships and the speed data are those obtained from actual flight-tests. While military airplanes have been employed because of the dependability of the data available on them, they are classified according to weights and used here as though they were commercial airplanes. The agreement between the proposed factors and those now used by the Department of Commerce is not perfect but is sufficiently close to indicate that load factors can be specified in terms of two of the variables which actually affect them instead of the single function, power loading, which is used at present. The constant 3.5 is purely empirical and further studies might necessitate modifying it or possibly breaking it down into other factors.

One such factor, which should be introduced in the maneuverability factor, is the length of the airplane, or the distance between the center of gravity of the airplane and the center of pressure of the tail surfaces. The latter distance has been considered once in the tail-surface constant but, since the damping due to the tail is a function of this distance squared, some provision for its introduction a second time should be made. As constituted at present, the proposed-factor formula gives the same result for the same values of R and K on small airplanes and on large bombers, although the

TABLE 1—COMPARISON OF LOAD FACTORS FOR HIGH ANGLE OF ATTACK

Gross Weight of Airplane, Lb.	Power Loading, Lb. per Hp.	Stalling Speed, M.P.H.	High Speed, M.P.H.	Speed Range Squared, R^2	Horizontal-Surface Constant K	Proposed Factor $3.5\,KR^2$	Department of Commerce Factor	Difference, Per Cent	Maximum Accelerometer Record in Pull-Out
1,940	21.50	45.0	83.3	3.43	0.313	3.76	6.50	−42.0	...
2,440	12.15	55.0	121.0	4.85	0.443	7.51	7.65	− 2.0	...
2,500	8.85	49.5	103.5	4.37	0.520	7.95	7.80	+ 2.0	...
2,550	14.20	52.0	102.0	3.85	0.520	7.00	7.35	− 4.8	5.5
2,580	6.10	58.0	162.0	7.80	0.351	9.60	9.85	− 2.5	10.5
2,950	7.20	58.7	167.0	8.10	0.371	10.50	9.15	+15.0	9.0
3,850	7.57	63.0	154.0	5.96	0.399	8.32	8.30	0.0	5.4
4,425	10.05	61.0	139.6	5.21	0.423	7.70	6.80	+13.0	4.2
4,590	11.27	62.0	133.0	4.60	0.348	5.60	6.35	−13.5	4.5
4,595	11.45	61.0	118.0	3.75	0.447	5.86	6.45	− 9.0	...
4,740	11.22	58.0	135.0	5.41	0.320	6.07	6.70	− 9.5	5.4
5,910	9.07	62.0	146.0	5.53	0.375	7.25	6.70	+ 8.0	...
6,450	16.00	55.0	115.8	4.41	0.407	6.30	5.30	+19.0	...
7,990	19.60	48.0	101.0	4.41	0.310	4.80	4.90	− 2.0	3.3
12,120	14.60[a]	60.0	99.0	2.72	0.346	3.30	4.65	−29.0	3.1
12,150	14.45[a]	56.0	99.0	3.13	0.342	3.75	4.65	−19.0	...
12,410	15.50	61.0	120.0	3.86	0.382	5.15	4.95	+ 4.0	...
13,740	17.40[a]	53.0	101.0	3.63	0.313	3.98	4.55	−12.5	3.0
16,840	21.05	55.0	112.0	4.15	0.398	5.78	4.40	+31.0	...

[a] Multi-engine.

longer fuselage on the larger ships will entail greater damping and, in conjunction with the larger loads involved on the controls themselves, will prevent the pilot maneuvering the large airplane as violently as the small one. Improvements in the way of further rationalization of terms in the proposed formula can doubtless be accomplished, and this is one of the possibilities, but the point to be made here is that a load-factor formula can be evolved which takes cognizance of more of the variables actually affecting the load than are used at present by the Department of Commerce or in the even more arbitrary factors established for military aircraft.

As indicated by Table 1, this is true so long as actual-speed ranges are used. In practice, however, the actual-speed range is not known until an airplane is built and flight tested, whereas execution of a set of airworthiness requirements based on factors of this sort would demand a knowledge of it while the design was still on the drafting board. The determination of the stalling speed is readily accomplished and a definite figure procured. From the administrative viewpoint, using methods giving reasonable but definite figures, although they are not always absolutely accurate, is necessary to avoid controversies concerning the legitimacy of assumptions made. This is especially true in the case of standard-performance computations for high speed in level flight. The Army or the Navy procedures give excellent results in the hands of experienced engineers but are altogether hopeless when attempted by the misguided geniuses who so frequently operate the back-yard type of airplane factory. Empirical formulas, of which many exist, or curves must be provided for such cases, and something similar to those given in Figs. 4 and 5 are suggested. They are taken from a set of charts prepared by the National Advisory Committee for Aeronautics about four years ago for estimating the performance of a so-called average airplane. As determined by their use in Table 2, they are slightly optimistic as to speed range, so the coefficient used in the proposed-factor formula was reduced to 3.25. Table 2 shows what can be accomplished by utilizing such curves for the determination of load factors. Four out of five of the errors exceeding 15 per cent are negative and would be greatly reduced or entirely eliminated by establishing minimum factors for airplanes of various weights, as is now done by the Department of Commerce when the power loading is in excess of 20 lb. per hp.

The method proposed here for determining the high-angle-of-attack load-factors can be improved by using other charts or formulas for determining speed-range or other coefficients, but the agreement shown between the values in Table 2 depending on two rational factors, one of which involves both of the factors used by the Department of Commerce, and those used by the Department suggests the possibilities of further studies to rationalize these factors.

For military ships or commercial airplanes in the acrobatic classes, the coefficient of 3.25 or 3.5 would need to be raised to 4.5 or 5 to bring the factors high enough to ensure that the physical endurance of the pilot rather than the strength of the airplane would be the limiting factor in establishing the maneuvers to be performed. To investigate this phase of the problem here or to draw conclusions from data on so few airplanes is impossible, however. All that is desired is to point out that rational functions can be introduced into the problem of evolving suitable load-factors and that

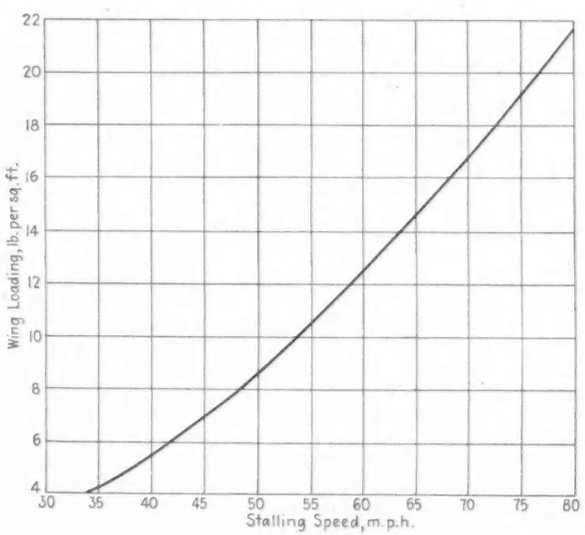

FIG. 4—STALLING SPEED AT SEA LEVEL FOR AN AVERAGE AIRPLANE

This Chart Was Prepared by the National Advisory Committee for Aeronautics Approximately Four Years Ago

TABLE 2—FURTHER COMPARISON OF LOAD FACTORS

Gross Weight of Airplane, Lb.	Wing Loading, Lb. per Sq. Ft.	Power Loading, Lb. per Hp.	Predicted Stalling-Speed, M.P.H.	Predicted Maximum-Speed, M.P.H.	Speed Range Squared R_p^2	Horizontal-Surface Constant K	Proposed Factor, $3.25\,KR_p^2$	Department of Commerce Factor	Difference, Per Cent
1,940	6.84	21.50	45.0	85	3.56	0.313	3.62	6.50	−44.0
2,440	8.76	12.15	51.0	116	5.18	0.443	7.47	7.65	− 2.5
2,500	8.85	12.40	51.0	115	5.09	0.520	8.60	7.80	+10.0
2,550	9.05	14.20	52.0	110	4.46	0.520	7.55	7.35	+ 3.0
2,580	10.25	6.10	55.0	156	8.04	0.351	9.16	9.85	− 7.0
2,950	12.20	7.20	60.0	156	6.76	0.371	8.16	9.15	−10.5
3,850	11.00	7.57	56.5	148	6.86	0.399	8.90	8.30	− 7.0
4,425	10.78	10.05	56.0	131	5.47	0.423	7.53	6.80	+11.0
4,590	9.32	11.27	51.0	121	5.61	0.348	6.35	6.35	0.0
4,595	10.45	11.45	55.0	125	5.16	0.447	7.50	6.45	+16.0
4,740	11.37	11.22	57.0	129	5.11	0.320	5.33	6.70	−20.0
5,910	13.18	9.07	62.0	146	5.53	0.375	6.74	6.70	+ 0.5
6,450	8.00	16.00	48.0	101	4.43	0.407	5.86	5.30	+10.5
7,990	8.30	19.60	49.0	95	3.75	0.310	3.78	4.90	−23.0
12,120	10.80	14.60[b]	56.0	114	4.14	0.346	4.67	4.65	+ 0.5
12,150	10.70	14.45[b]	56.0	115	4.21	0.342	4.70	4.65	+ 1.0
12,410	10.90	15.50	56.0	111	3.93	0.382	4.87	4.95	− 1.5
13,740	9.17	17.40[b]	52.0	102	3.85	0.313	3.92	4.55	−14.0
16,840	10.22	21.05	55.0	100	3.31	0.398	4.20	4.40	− 4.5

[b] Multi-engine.

the results will compare favorablly with the requirements established by experience. In any case, a certain empiricism or arbitrariness in the use of coefficient is to be expected so long as the adoption of theoretical factors without modification is impossible. In the past, objection has been made to the rationalization of factor formulas on the ground that such arbitrary coefficients were always introduced somewhere in the procedure and one might just as well accept an arbitrary load-factor itself as one that depended partly on an arbitrary coefficient. This objection is still valid, but to a slighter extent than five years ago. We now have more data procured by research and more accumulated from experience, so we can break our problem down into smaller components and by doing so find that some can be rationalized while some must still depend on empirical factors and the judgment of the engineer who is confronted by them.

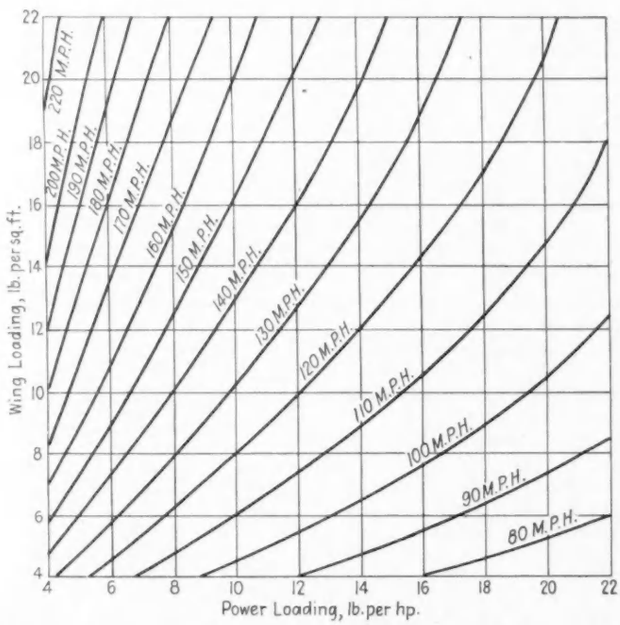

FIG. 5—MAXIMUM SPEED IN LEVEL FLIGHT AT SEA LEVEL FOR AN AVERAGE AIRPLANE

These Curves Are from the Same Series of Charts as Those in Fig. 4

The high-angle-of-attack condition for the wings assumes an abrupt pull-out from a glide or dive at a speed considerably higher than the stalling speed at $K_{y\,max}$ and generally higher than the speed in normal level-flight. The pull-out requires the pilot to manipulate his controls so that the elevators are raised to, or very near, their maximum upward position. A load of considerable magnitude is developed on the tail surfaces, therefore, when the airplane is maneuvered to the high-angle attitude. Designing the tail surfaces for this condition has been found advisable, and establishing the maximum initial-velocity for the abrupt pull-out is necessary to have a reasonable correlation between the strength of the wings and that of the tail for this condition. This can be found from $V_{max} = V_s\sqrt{\text{High-Angle Load-Factor}}$. By proportioning that portion of the tail surfaces affected by the pull-out loading for this velocity, the strength of tail will not be out of proportion to that of the wings. This relation between velocities can be used regardless of whether the high-angle load-factor for the wings is based on speed range for commercial airplanes or the limit of the pilots in military ships. As for the magnitude and distribution of this load, more will be said later.

Other Conditions To Be Considered

The methods and factors so far considered have had to do with pull-ups from steady flight at one attitude to the attitude at which the lift coefficient was the maximum. Considering what other conditions should be provided for is now necessary and Fig. 6 has been drawn to assist with that problem. Instead of using the tapered wings and tapering spars of the PW-9, Fig. 6 is based on constant-chord wings of the same airfoil section and carrying the same total load as the PW-9 wings. Spars are assumed at 15 and 65 per cent of the chord, which is a reasonable location. For these conditions the loads on the rear spar would reach the maximum in the high-angle-of-attack condition if the pull-out were made at terminal velocity, since the load factors developed by such a maneuver are so high as to offset the effects of center-of-pressure travel.

We have already concluded, however, that to pull up to the high-angle attitude at terminal velocity without exceeding practicable load-factors is impossible, so our investigation must be carried further if we are to ob-

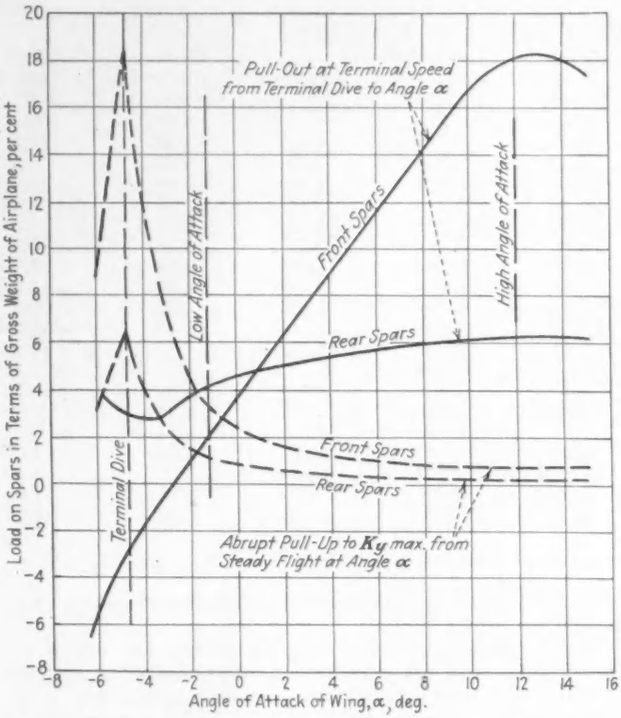
Pull-Out at Terminal Speed from Terminal Dive to Angle α
Low Angle of Attack
Front Spars
High Angle of Attack
Rear Spars
Front Spars
Rear Spars
Terminal Dive
Abrupt Pull-Up to Ky max. from Steady Flight at Angle α
Load on Spars in Terms of Gross Weight of Airplane, per cent
Angle of Attack of Wing, α, deg.

FIG. 6—VARIATION IN LOAD ON SPARS FOR DIFFERENT ANGLES OF ATTACK

This Chart Was Prepared for Wings Having a Constant Chord and with the Spars Located at 15 and 65 Per Cent of the Chord

tain a condition for the design of the rear spars. Military airplanes have been, and are being, dived to terminal speeds, and having them brought out to a condition of level flight before they reach the earth is, of course, desirable. Hence, they must pull out from dives at terminal speed and pass through the small angles of attack in which the center of pressure for the normal airfoil is at 50 or 60 per cent of the wing chord. More accelerometer and velocity data should be obtained during mild pull-outs from high-speed dives on both military airplanes and the acrobatic types of commercial aircraft so that relationships can be established between angle of attack, air-speed and acceleration. Present indications are that even in mild pull-outs the first few degrees of change in the angle of attack are accomplished with almost no decrease in velocity, so that, no matter what angle is established for this low-angle-of-attack, center-of-pressure-back, condition, a pursuit ship or diving bomber must be considered as capable of passing through that attitude at very nearly terminal diving-speed.

The one factor in our favor in this condition is that theoretical factors cannot approach those for the high-angle attitude since they are no longer a function of $(V_t/V_s)^2$ but of $(V_t/V_0)^2$, where V_t is the actual terminal diving or some arbitrarily established maximum speed and V_0 is the velocity at which level flight could just be maintained at the low angle of attack under consideration. To have some specific values, let us assume an airplane where $V_l = 3\,V_s$ and $V_t = 2\,V_l = 6\,V_s$. This would represent a good clean airplane but is not an impossibility. Taking our low-angle criterion in accord with present standards, $K_y = 1/4\,K_{y\,max}$, $V_0^2 = 4\,V_s^2$ or $V_0 = 2\,V_s$. A pull-out at $V_t = 6\,V_s$ would then produce a load factor, $F = (V_t/V_0)^2 = (6/2)^2 = 9$, which is very different from the 24 indicated by like theory for the high-angle factor. However, the fact that this factor can be attained on airplanes for which dives to terminal velocity are anticipated must be borne in mind, whereas pull-outs to the high-angle condition cannot be made without exceeding practical limitations. If the low-angle criterion is made the angle at which $K_y = 1/6\,K_{y\,max}$, the center of pressure is farther back on the wing but the theoretical factor would be reduced to 6 for the conditions established above and probably the load on the rear spars would be less for normal spar-locations and normal center-of-pressure movements.

The criterion for the low-angle-of-attack condition is thus seen to be a function of $(V_t/V_0)^2$, of spar position and of center-of-pressure travel, so that the severest loading on the rear spar will occur with different attitudes for different wings. In view of the success that has followed the use of the present low-angle criterion, that it conform to the angle at which $K_y = 1/4\,K_{y\,max}$, no good reason apparently exists for making any change and the attitude should be maintained as at present, at least until correlated accelerometer, speed and angle-of-attack data are available.

A step toward rationalization can be made by making the load factor for a given case depend on the ratio of $(V_t/V_0)^2$. Such a speed can be determined for given low-angle-of-attack factors and a given low-angle attitude by a very simple process. For instance, a transport designed for a low-angle factor of 3.5 would have $V_t = \sqrt{[3.5/1.5]}\ V_0 = 1.53\ V_0$. But if the low-angle-of-attack attitude is that for $1/4\,K_{y\,max}$, $V_0 = 2\ V_s$, approximately, hence, $V_t = 3.06\ V_s$. This would indicate a limiting diving speed of 183 m.p.h. for a ship landing at 60 m.p.h., which seems sufficiently high for a cabin transport. With the limiting velocity thus established, designing tail surfaces, wings and fuselages to carry the loads involved becomes possible and hence makes for a more rational analysis than the unrelated conditions used at present.

Diving to Terminal Velocity

For airplanes that are to be dived to terminal velocity, the velocity can be determined by the methods used by Roché[5]. A less tedious procedure is to obtain V_t from the following formula:

$$V_t = \sqrt{[(V_l^3 \times W_g)/(375\,\eta_{max} \times \text{b.hp.})]} \qquad (1)$$

where

b.hp. = engine horsepower
V_l = high speed in level flight in miles per hour
V_t = actual terminal dive or some arbitrarily established maximum speed in miles per hour
W_g = gross weight of the airplane in pounds
η_{max} = maximum propeller efficiency

Differences in wind-tunnel data alone frequently will result in errors greater than those introduced by using

TABLE 3—COMPARISON OF TAIL LOADS IN A DIVE AND A PULL-UP

Airplane	Normal Loads in Steady Dive K_{mcg}	K_{mo}	Normal Loads in Pull-Up From V_{lim}	Fahrney and Gilbert[c]	Rhode[d]
F6C-4	1,359	1,465	190	1,749	1,812
PW-9	1,480	1,565	190	1,302	1,206
B-2	9,500	10,300	120	2,974	1,950
A-3	1,920	2,220	160	1,640	1,692
PT-3A	680	687	160	1,282	....
LB-7	5,000	4,940	120	2,850	2,935

[c] See Design Loads for Horizontal Tail-Surfaces, a thesis presented to the Massachusetts Institute of Technology in 1930.

[d] See Air Forces and Moments Acting on Airplanes, by J. A. Roché, Materiel Division A.D.M. No. 1119.

[5] See Air Corps Information Circular No. 650 entitled Proposed Method of Determining Design Tail Loads for Airplanes, by J. A. Roché.

Formula (1). For instance, Lieutenants Fahrney and Gilbert found[9] that, by using Göttingen tunnel data on the Göttingen 436 section, they obtained a terminal velocity of 330 m.p.h. against the 312 obtained by Roché[10]. A value of 312 m.p.h. for V_t was also obtained from this formula. With the terminal diving-speed known, the low-angle load-factor can be obtained as the ratio $(V_t/V_0)^2$, as has been mentioned previously in this paper.

Conditions during the dive itself differ from those in either of the attitudes just considered, since the net lift on the wings is nearly zero. A downward load is acting on the front spar and an upward one on the rear, the center of pressure being at the center of pressure of the horizontal tail-surfaces. The total load on the rear spar is, therefore, greater than that on the front by an amount which just equals the tail load, at least at the terminal velocity. This condition would not exist exactly at lower velocities, but the angle of attack at such velocities will be found to be so close to the angle of zero lift that satisfactory loads can be obtained by using the airfoil properties for zero lift. The tail load is then found from

[9] See Design Loads for Horizontal Tail Surfaces, by Lieut. D. S. Fahrney, U. S. N. and Lieut. W. C. Gilbert, U. S. N., a thesis presented to the Massachusetts Institute of Technology in 1930.

[10] See Air Corps Information Circular No. 650 entitled Proposed Methods of Determining Tail Loads for Airplanes, by J. A. Roché.

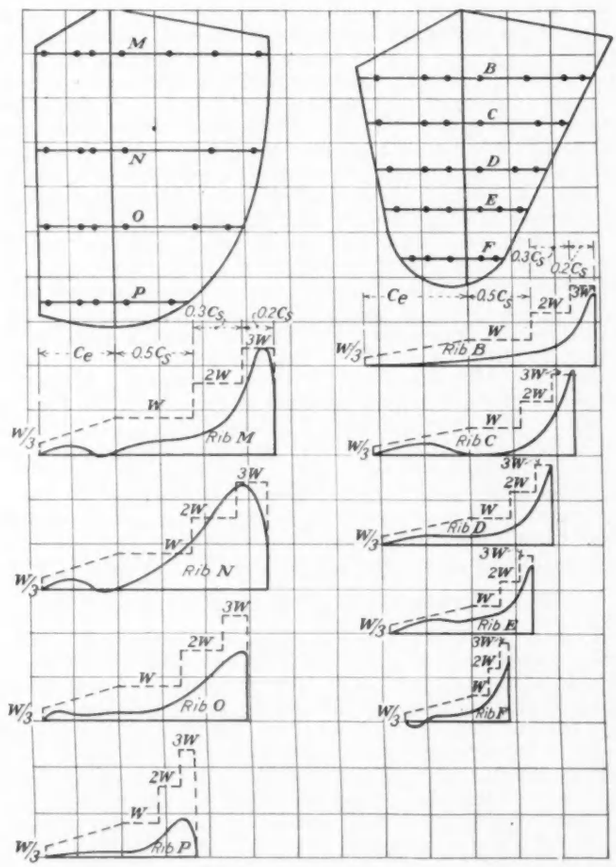

FIG. 7—COMPARISON OF PROPOSED AND ACTUAL PRESSURE-DISTRIBUTION OVER TAIL SURFACES IN A DIVE

The Tail Surfaces Considered Are Those of the PW-9 and F6C-4 Airplanes, the Data on Which the Curves Are Based Having Been Taken from National Advisory Committee for Aeronautics Reports Nos. 364 and 307 Respectively

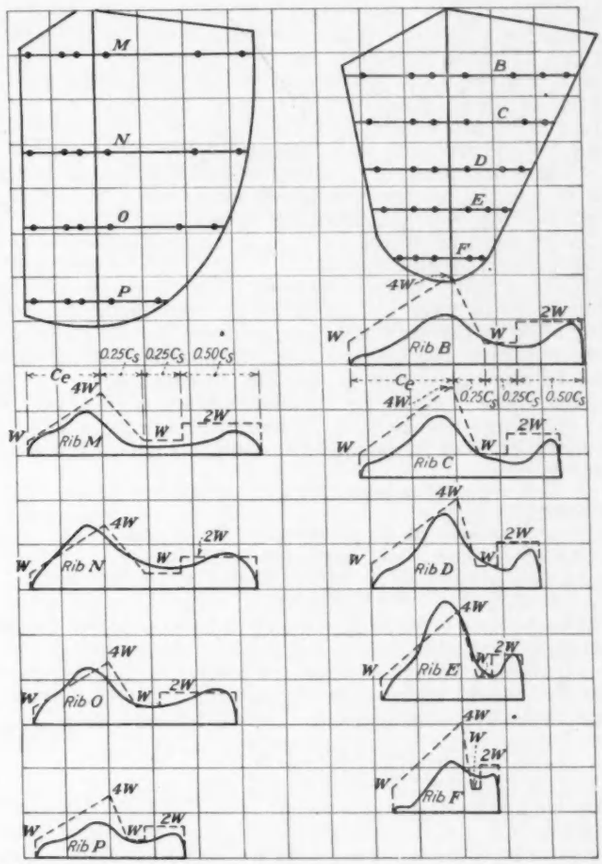

FIG. 8—PROPOSED AND ACTUAL DISTRIBUTION OF PRESSURE OVER TAIL SURFACES IN A PULL-OUT FROM A DIVE

The Tail Surfaces and the Sources of the Data Used in Plotting Are the Same as Those for Fig. 7

$$W_t = K_{mo} \times (C/L) \times S_w \times V_t^2 \qquad (2)$$

where

C = wing chord in feet
K_{mo} = moment coefficient at zero lift
L = distance between the center of gravity of the airplane and the center of pressure of the tail in feet
S_w = wing area in square feet
V_t = terminal speed in miles per hour
W_t = tail load in pounds

Table 3 shows the variation to be expected for conditions in a steady dive at terminal velocity when the moment coefficient about the center of gravity of the airplane is used and when K_{mo} is used. These data are from the thesis of Lieutenants Fahrney and Gilbert. The less tedious process of using K_{mo} is generally about 10 per cent on the conservative side.

Having obtained the tail load, the loads on the wings can be determined for K_{mo} and V_t and distributed as a downward load on the front spar and upward on the rear, the total load on the rear being equal to that on the front spar plus that on the tail surfaces. A chord component on the wings equal to the gross weight of the airplane should be used in conjunction with the above dive loads on the spars. This agrees with present practice and experience seems to vindicate its use.

With such a method of procedure we can obtain tail loads for abrupt pull-ups that are directly related to the high-angle-of-attack attitude and for conditions during a terminal dive or during a mild pull-out that are related to the wing loads in a terminal dive or in

the limited dive established for the low-angle-of-attack condition. In either case the magnitudes and distributions of these tail loads must be considered. Lieutenants Fahrney and Gilbert propose[11] a distribution for each of these cases which agrees very well with the results of pressure-distribution tests on the F6C-4 and the PW-9 airplanes, as is shown by Figs. 7 and 8.

Their proposal for computing the tail load in a dive is to use the moment coefficient at zero lift for the airfoil section and the limiting speed for the dive. In developing the curves in Fig. 7, these limiting speeds conformed to the speeds at which the pressure-distribution data were obtained. The proposed distribution is to have a load of $3W$ extend from the leading edge of the stabilizer to a point 0.2 of the stabilizer chord behind the leading edge, thence $2W$ for the next 0.3 of the chord and W for the remaining 0.5 of the chord. The load on the movable surface varies from W at the hinge line to $\frac{1}{3}W$ at the trailing edge. The intensity of load in pounds per square inch is given by the equation

$$W = W_{total}/(245S_s + 96S_e) \qquad (3)$$

where

S_e = area of the elevator in square feet
S_s = area of the stabilizer in square feet
W = intensity of load in pounds per square inch
W_{total} = total load on the tail in pounds

The proposal for the pull-out is to superpose a load equal to that obtained if the elevator be regarded as a flat plate at an angle of attack of 25 deg. on the load that the tail would carry in a dive at the limiting velocity established for the pull-out. The total load then is

$$W_{total} = [K_{m_0} \times S_w \times (c/L) \times V_{lim}^2] + [0.00202 \times S_e \times V_{lim}^2]$$

The load is distributed so that it is $2W$ over the leading 0.5 of the stabilizer chord, W over the next 0.25 of the chord and a uniformly varying load increasing from W to $4W$ over the last 0.25 of the stabilizer chord. The load on the elevator runs from $4W$ at the hinge line to W at the trailing edge. The intensity of load in pounds per square inch can be found from $W = W^{total}/(270S_s + 360S_e)$ for this distribution. When the load on the elevator is greater than can be exerted by the pilot, that is, when the load produces a force on the stick or wheel greater than 300 lb., the flat-plate portion of the load due to the elevator being actuated may be reduced so that the total load on the elevator is equal to that which the pilot can apply through the control system.

Table 3 shows comparative loads obtained by Fahrney and Gilbert's recommended procedure with their assigned limiting pull-up speeds and those obtained by the formula developed by R. V. Rhode, the constants for which are based on the results of the F6C-4 and PW-9 tail-surface tests. The Rhode formula is therefore applicable to pursuit ships in particular but appears to give reasonable results when applied to other types. It is

$$W_{hts} = [0.00544\ (S_e/S_t)^{1.59}]\ S_t F_h V_s^2 \qquad (4)$$

where

F_h = high-angle-of-attack load-factor
S_e = area of elevator in square feet
S_t = total area of tail surfaces in square feet
V_s = stalling speed of airplane in miles per hour
W_{hts} = total load on horizontal tail-surface

Both of these procedures involve the elevator and the total tail-surface areas, as is rational. Rhode's formula establishes the limiting velocity as $V_{lim}^2 = F_h V_s^2$ where the Fahrney and Gilbert results were based on an arbitrarily established limiting velocity in this case. Other possible limitations for velocity have already been mentioned.

Inverted Flight

The last of the four design conditions ordinarily specified, that for inverted flight, was originally established to provide a condition that would take care of the reversals of load occurring when an airplane is suddenly nosed down from level flight or is flown on its back. Outside loops were not considered as probable, although their possibility was recognized, and designers felt that a more or less arbitrarily established condition would suffice. It has for several years and has been very satisfactory from the viewpoint of structural airworthiness.

With the advent of the outside loop and similar maneuvers, revising this condition for pursuit types and diving bombers probably will be necessary. Before anything rational can be done, however, airfoil data for negative angles of attack well below the angle of zero lift must be obtained, as such data are practically non-existent today. Data showing the relative distribution of load between wings will need to be secured for inverted flight and would be desirable in all other attitudes and, last, but far from least, full-flight accelerometer-data in bumps, push-overs, outside loops and plain upside-down flying are necessary. Various agencies are now at work to accumulate the last group and a substantial volume of useful results should be available before long.

In all probability a high-angle inverted-flight condition analogous to that in normal flight will be found to exist and rationalizing load factors and providing for such a condition may be possible. To attempt to do so at present, however, appears to be a futile occupation in view of the almost complete absence of airfoil and other basic data at inverted-flight attitudes. Until such data are procured, following present requirements for inverted flight and hoping that this condition may be eliminated entirely in the future in view of the proposed modifications to be made in the dive requirements would seem desirable. The nose-dive condition results in a heavy downward load on the front spars and, by designing a biplane structure so that the load on the front truss could be taken either by the front landing wires or the incidence wire, the investigation of both being required, the dive condition would probably be found to suffice for designing conventional types of airplane. It will almost certainly be the limiting factor in the case of monoplanes. That the dive load acting on the rear spar at terminal or limiting velocity will exceed the corresponding loads in low angle of attack so that the latter condition can also be eliminated for conventional biplanes is also possible. Such possibilities are of sufficient importance to warrant extended investigations that are beyond the scope of this paper.

Two Classes of Load Factors Proposed

To sum up the factors and conditions presented here, two categories should be established; one for pursuit ships, diving bombers and similar craft that must be brought out of dives at terminal speed and the other for commercial or non-acrobatic military types for which limiting maximum diving-speeds can be established. For the acrobatic types the load factors for the high-angle attitude should be based on the maximum accelerations possible in a squash pull-out or the maximum values that a pilot can survive without a prolonged loss of faculties or physical injury. Having determined the limiting accelerations and introduced the desired factor of safety of 1.5, or whatever is required, the limiting velocity for an abrupt pull-up can be established and the load on the tail determined. The loads in the low-angle attitude would depend on the loads possible in mild pull-outs at terminal speeds and would be

[11] See Design Loads for Horizontal Tail Surfaces for Airplanes, by Lieut. D. S. Fahrney, U. S. N., and Lieut. W. C. Gilbert, U. S. N., a thesis presented to the Massachusetts Institute of Technology in 1930.

determined from the ratio of velocity in a terminal dive to that in level flight at the angle decided upon for this condition. The nose-dive condition would be based on a vertical dive at terminal speed and the inverted-flight condition would be retained for modifying or eliminating it.

For the non-acrobatic and commercial types the high-angle factors would be established in terms of speed range and a suitable maneuverability factor, or in terms of some similar characteristics of the airplane. With the factor established, the maximum speed for an abrupt pull-up could be determined and the loads on the tail surfaces evaluated for this condition. Having based the high-angle factor on characteristics of the airplane giving results that agree with experience, the low-angle-attitude factors would be tempered by experience and established as 65 or 70 per cent of those in high angle and the attitude itself would be established in terms of lift coefficient, center-of-pressure position or a similar characteristic of the airfoil. The low-angle factor would automatically establish the maximum diving-speed for the airplane and so furnish data for the dive condition on the wings and the design load for the tail. The inverted-flight condition would remain as at present pending further studies.

The methods, as proposed, involve rational approximations to reduce the tedium of stress-analysis procedure and to provide definite values that will eliminate controversies in the administration of requirements. Many designers will, I believe, agree that attaining both of these objectives is not only permissible but also highly desirable.

THE DISCUSSION

R. C. GAZLEY[12]:—Mr. Newell is to be highly commended for his thorough and practical treatment of a problem that has rapidly been assuming real importance in the field of aircraft design. Some such method as he proposes is not only advisable but is definitely required in the interests of safety and reliability. I wish particularly to congratulate him on his ability to attack such a complicated problem in a manner that is theoretically correct, yet simple and practical. We are greatly indebted to abstract theoretical studies along many lines, but in this case a compromise between pure theory and practical considerations is necessary to make the results immediately useful to the industry. We concluded, I think very logically, that Department of Commerce load-factors for the average airplane up to and within approximately two years ago produced satisfactory results and no reason for greatly increasing them seemed to exist. We wanted to take care of the increasing spread in the range of the speeds and maneuverability, as they would become apparent in later design.

I have, at Mr. Newell's request, made a study of a representative group of commercial airplanes and have prepared Table 4, which corresponds with Table 1 of his paper, the estimated performance being obtained from his charts. This table shows that for 20 airplanes the proposed method gives 8 load factors considerably below the present Department of Commerce factors while 2 are considerably above. The rest are in fairly close agreement. An examination of the data on the airplanes having low proposed factors shows that all but one have rather low values of K, the horizontal-surface constant, and that in almost every case the true high speed of the airplane is considerably greater than the estimated high speed. As Mr. Newell points out, his chart is pessimistic for the high-speed airplanes. Consequently, we get, as would be expected, load factors that are probably too low for the high-speed aircraft. In the case of the two airplanes having high proposed factors, both load factors would be reduced to Department of Commerce values if an average value of K were used instead of the high value found for each airplane.

These observations tend to show that the value of K has too much influence on the load factor and that the method as presently outlined does not differentiate between high-speed airplanes of very clean design and

[12] M.S.A.E.—Chief of the engineering section, aeronautics branch, Department of Commerce, City of Washington.

TABLE 4—COMPARISON OF LOAD FACTORS FOR HIGH ANGLE OF ATTACK BASED ON REVISED DEPARTMENT OF COMMERCE CHART

Gross Weight, Lb.	Wing Loading, Lb. per Sq. Ft.	Power Loading, Lb. per Hp.	Predicted Stalling-Speed, M.P.H.	Predicted Maximum-Speed, M.P.H.	Speed Range Squared R^2	Horizontal-Surface Constant K	Factor $3.5\,KR^2$	Department of Commerce Factor	Difference, Per Cent
842	7.50	18.70	45	94	4.38	0.435	5.40	6.70	−20
875	6.16	24.30	42	78	3.43	0.580	6.95	6.50	+ 7
1,167	7.20	21.20	46	87	3.58	0.555	7.00	6.50	+ 8
1,402	14.76	11.20	64	140	4.85	0.392	6.65	7.85	−18
1,580	8.40	18.60	49	97	3.92	0.392	5.40	6.70	−19
1,790	7.45	17.90	47	94	4.00	0.471	6.60	6.75	− 2
1,820	9.50	18.20	52	102	3.85	0.456	6.15	6.70	− 8
1,900	7.90	17.30	48	98	4.15	0.300	4.40	6.85	−36
2,600	11.60	14.10	58	118	4.16	0.373	5.45	7.20	−24
2,814	10.43	9.37	54	135	6.25	0.398	8.70	8.35	+ 4
3,200	14.80	7.10	64	167	6.87	0.375	9.05	9.00	0
3,350	12.50	11.16	60	133	4.92	0.330	5.70	7.30	−22
3,965	13.20	13.20	62	127	4.20	0.278	4.00	6.30	−36
4,000	14.40	13.30	64	130	4.08	0.380	5.40	6.30	−14
4,075	14.90	13.60	66	131	3.92	0.430	5.90	6.20	− 5
5,265	14.90	8.78	66	154	5.48	0.393	7.50	6.80	+11
5,300	16.90	9.21	70	158	5.10	0.376	6.70	6.70	0
8,000	15.00	13.90	66	129	3.84	0.477	6.40	5.30	+21
8,600[e]	17.55	19.00	72	118	2.70	0.392	3.70	4.90	−24
14,000[e]	16.76	15.90	70	128	3.35	0.485	5.70	4.80	+19

[e] Multi-engine.

slow airplanes having considerable parasite drag. These two points will be discussed further, but first let us see just what the quantity speed range squared means.

Suggested Formulas To Cover Airplane Size and Speed

Certain reasonable assumptions having been made, the square of the speed range is exactly the applied load-factor, or acceleration in terms of g, experienced by an airplane when it is pulled up from level flight at maximum speed to the stalling angle. The most important assumption to be fulfilled is that the stalling angle, or angle of maximum lift-coefficient, is reached without loss of initial velocity. This will be very nearly accomplished if the tail coefficient K is large enough. Since available data do not show just what value of K is required for a given airplane to approximate this condition, a reasonable assumption would be that all airplanes are capable of executing this maneuver without appreciable loss of speed if the controls are sufficient for landing and other ordinary maneuvers. In this case no necessity for the inclusion of K in the formula exists. This would make for simplicity and would obviate the necessity for revising the load factor for every change in horizontal control-surface area. Manufacturers who must at present revise the flying load-factors for every change in horsepower will certainly frown upon the inclusion of such a variable function as tail-surface area in the formula. With the factor K omitted, the formula would take the form

$$\text{Load Factor} = C \times (V_1/V_s)^2 \qquad (5)$$

The constant C would represent an arbitrary factor of safety which should probably be further modified by including some function of gross weight to reduce the value of the constant as the size of the airplane increases. This would be in accordance with the present practice and would account roughly for the inertia effect of the heavier airplanes which prevents them from being rapidly maneuvered.

If any type of formula that includes high speed is adopted, devising some method of estimating high speed which will be simple to apply but which will take into account the pronounced effects of wing arrangement, clean design, retractable chassis and other refinements will be necessary. Mr. Newell's suggestion that charts be used could be adopted, provided that the charts were modified to cover several classes of airplane. This might be done conveniently by applying a correction factor to the speed obtained from the chart. Using an approximate formula of the type given below might also be possible

$$V = C_1\sqrt[6]{(\text{Wing Loading}/\text{Power Loading})} \qquad (6)$$

where the constant C_1 would have a range of values covering all types of airplane. In any case, the point to be emphasized is that providing for the high-speed airplane without penalizing the slower type is absolutely necessary.

Recent studies by R. V. Rhode and E. E. Lundquist of the National Advisory Committee for Aeronautics have shown that the loads produced by bumps, or gusts, are serious enough for consideration in design. Incidentally, I do not think Mr. Newell emphasized that point sufficiently. We have made a study of a number of typical airplanes in accordance with the Committee's latest report on vertical gusts. Although I do not remember the exact figures, I believe we obtained load factors of approximately 4 in some cases, that being the medium-angle-of-attack load-factor which cannot be compared directly with the specified high-angle factor. At any rate, on some airplanes the differences between possible applied load-factors in vertical gusts and actual design loads for the wings were very slight, so that the need for consideration of this subject really is serious. The formula that Rhode and Lundquist have derived to express load factor involves the high speed of the airplane and the reciprocal of wing loading. The use of speed range squared as a basis for load-factor determination covers this condition indirectly, since the square of the speed range can be broken down into an expression proportional to the square of the high speed divided by the wing loading. Thus the proposed formula becomes more conservative as the high speed is increased, as far as bumps are concerned.

In connection with Mr. Newell's proposals for determination of design tail-surface loads, the equation for tail load may give results that are too low for design purposes when applied to an airfoil having a low moment-coefficient. This applies particularly to stable airfoils. One way of overcoming this difficulty would be to adopt the English practice of specifying a minimum value, obtained empirically.

The foregoing comments apply particularly to commercial airplanes. As Mr. Newell has brought out in his paper, a distinct difference exists between the conditions that determine design loads for military and for commercial aircraft. This should be recognized more and more as the science progresses, and the users of commercial aircraft should be made to understand that an approved-type certificate will not always prevent a pilot from pulling the wings off, if he tries hard enough.

Pilot's Physiological Resistance and Plane's Strength Determine Design

LIEUT. R. D. MACCART, U.S.N.[13]:—The Bureau of Aeronautics has long recognized the necessity for improvement in the present method of specifying load factors, and the author is to be congratulated on his initiative in studying this subject and his courage in presenting the results. This is a matter which vitally concerns the designer and constructor and regarding which a wide divergence of opinion is bound to be found among engineers who have given thought to the subject of load factors.

Some Naval airplanes are of the so-called unrestricted type and others are restricted. Unrestricted airplanes are those which supposedly are strong enough structurally to withstand any maneuvers that the pilot can stand without physical injury or extreme discomfort. This statement is practically correct for non-inverted maneuvers. Even unrestricted airplanes are insufficiently strong at present to withstand inverted maneuvers that are within the capacity of the pilot to withstand, such as the inverted pull-out or pull-up. Obviously, therefore, all airplanes must be restricted, the restrictions to be determined by the physiological resistance of the pilot or by the strength of the plane.

Airplanes are built to perform certain maneuvers which differ for each class of airplane. The first step in any load-factor-determination procedure should be a decision as to the required maneuvers. The following is believed to be a logical method of stating the various factors involved in the case of a single-seat fighting airplane which is assumed to be unrestricted. This means that it is to dive vertically and pull out at terminal speed and perform all acrobatic maneuvers. It is not to perform these maneuvers in the inverted attitude except that it is to fly in the inverted attitude at maximum inverted speed for level flight and to flat glide without an acceleration pull-out.

Maximum Accelerations Possible under Various Conditions

Obviously, the maximum acceleration is obtained in the vertical terminal-dive small-radius pull-out, and probably, in the case of a high-performance readily ma-

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neuverable plane having a conventional airfoil, the low-angle-of-attack condition at least will be designed by this maneuver. For a maximum speed-range of 5, which is the usual range for modern fighting airplanes, the applied acceleration at terminal velocity and at 25 per cent of maximum lift will be 6.25. The maximum acceleration that can safely be sustained by what might be called the high-acceleration pilot may be 9, although the average pilot will not voluntarily accept, even momentarily, as high an acceleration. At high momentary accelerations and at low accelerations extending over a relatively longer interval of time, a pilot will go blind or his vision become hazy, even though he has full use of his other faculties. Since a blind pilot is helpless until his vision returns, pilots will not maneuver an airplane so that they will lose vision except momentarily and will voluntarily, or involuntarily, take steps to correct the attitude of the plane at or before this point by easing the stick forward. This action, if taken near the blind point, will not necessarily prevent the plane from getting a higher acceleration or prevent the pilot from going blind, because of the appreciable time that is required to reduce the airplane's rotational acceleration and to change the rate of rotation, but this action by the pilot will prevent more than a definite small increase in acceleration above the acceleration at which the action was started.

If this reasoning is correct, tests can readily establish these important accelerations, and they must be known before load factors for this maneuver, low incidence, can be established. The Bureau has initiated a comprehensive test-program to give the desired results.

Even in the most modern fighting-airplanes, an acceleration of 9, if obtained, probably will occur at an angle above that corresponding to the standard low-incidence condition. This condition probably will also determine the design of the front beam, but, if it does not, the high-angle-of-attack load-factor should be set not higher than the theoretical maximum applied-acceleration at the level-flight high speed increased by a factor of safety, except that the maximum applied-acceleration should not exceed the physical limitations of the pilot. The terminal-dive beam-loads or factors should be those, including drag loads, required to maintain the airplane in the steady no-lift dive when balanced by the tail load and including a factor of safety.

The inverted-flight condition should have, for the present, due to lack of data, an arbitrary load-factor of not less than 4. Other maneuvers will not be critical on account of the relatively low accelerations involved. The unsymmetrical condition should be designed as at present.

Terminal-Dive Beam-Loads

In the foregoing example, the terminal-dive beam-loads probably will not be critical. This leaves the low-angle-of-attack condition which is critical in the dive pull-out for the rear beam and probably for the front beam; also, the high-angle-of-attack condition which may be critical for the front beam in the pull-up from level or inclined flight. The terminal dive may be critical for the drag system, although more probably the design of the drag members will be determined by an acceleration condition.

Investigating the trend of beam loads beyond the angle of maximum lift and above the angle of 25 per cent of maximum lift is necessary so that the angle at which the pull-up and pull-out loads are the maximum for each beam can be determined.

Similar reasoning may be used for each class of airplanes, both service and commercial. Conceivably, the giant airplanes of the future will have load factors approximating very closely the accelerations due to bumps and air disturbances and will be flown so that the accelerations due to necessary changes in attitude will not be critical. In this connection, R. V. Rhode's paper[14] contains important information which should be given careful consideration.

The Bureau has made a careful study with a view to obtaining a procedure that will enable load factors and design conditions to be accurately determined and has, in collaboration with the National Advisory Committee for Aeronautics, initiated the necessary test programs to obtain the information that, as stated in the paper, is so vitally necessary for the success of any non-empirical procedure.

Linking Nose-Dive and Tail-Loading Conditions with Angle of Attack

ALFRED S. NILES[15]:—At present the chief defects of our rules for computing the design loads for airplane structures are the lack of rational connection between some of the loading conditions and the very arbitrary character of the requirements for the tail surfaces and the loads on the wings in the nose-dive condition. The author has proposed some minor changes in the rules for determining the design load-factors for the wings in the high and low-angle-of-attack conditions, but, as the resultant change for any specific design is small, these proposals are of importance only as they put the requirements on a slightly more rational basis than at present. The chief merit of his paper is that he suggests a practicable method of linking the nose-dive and tail-loading conditions with those for high and low angle of attack. Detailed study of the effects of his proposal may show that they should be modified in minor particulars, but the presentation of his paper should lead to a revision in the near future of at least the nose-dive and tail-loading rules along the lines he suggests.

In the past the chief obstacle to a rational linkage of the nose dive with the other flying conditions has been the difficulty of deciding upon the allowable speed of dive for a given design, and the widely held idea that pulling up sharply from a dive of that speed to the angle of maximum lift-coefficient in safety should be possible. As long as an attempt is made to hold to this criterion, the maximum allowable-speed will be equal to the stalling speed multiplied by the square root of the high-angle-of-attack load-factor divided by the desired factor of safety. As soon as we begin to investigate existing types on this basis, we find that the maximum allowable-speed is either too low for tactical requirements, either military or commercial, or the high-angle-of-attack load-factor must be made so high that the allowable military or commercial payload is inconsiderable. Since nearly all existing designs are structurally adequate to carry the loads actually imposed upon them, the investigator soon comes to the conclusion that this method of solving the problem is unsatisfactory and usually lets the matter drop.

The author has pointed the way to a practicable solution by the device of considering two diving speeds. The first, which I will refer to as the safe pull-out speed, is the maximum from which the airplane can be pulled up sharply without danger of structural failure. The second, which I will call the maximum allowable-speed, is one at which the airplane can dive safely, but from which it should be pulled up gently and with care. Since airplanes cannot be designed to be commercially or militarily efficient and at the same time too strong to be broken in the air by a reckless pilot, setting up reasonably attainable standards of strength and working out rational loading-rules in connection with those standards would appear desirable. Using these two diving speeds, one in connection with the high-

[14] See S.A.E. JOURNAL, September, 1931, p. 179.

[15] Professor of aeronautic engineering, Stanford University, Stanford University, Calif.

angle and the other in connection with the low-angle-of-attack loading-condition, the author has shown the way to obtain reasonable and coordinated loadings for the tail and nose-dive condition. The reasonableness of the resulting tail and nose-dive loads would depend on the selected high and low-angle-of-attack loadings, but that in itself would be a great advance over the present situation, and any improvements in the methods of specifying the two basic conditions would be reflected in the others.

In discussing present requirements for high-angle-of-attack load-factors, the author states that they are based on a single variable, power loading, whereas they actually are based on two variables, power loading and gross weight. For non-acrobatic designs he proposes a formula based upon the speed range and the horizontal-surface constant, with the further possible addition of the distance from the center of gravity to the tail surfaces. Unless this third variable is introduced, the proposed method does not introduce any larger number of variables than the present method, but the variables used are more pertinent to the problem and the results correspondingly more rational.

As stated by the author, administrative problems require that some definite and simple method for computing the speed range be adopted, and those interested should decide whether the proposed curves would be satisfactory or some alternative curves should be adopted. The value to be used for the arbitrary constant should also be discussed, though the figures given by the author indicate that his proposed figure of 3.25 is reasonable. A third item that should be decided upon in this connection is the required precision of the result, whether the airplane should be designed to the nearest hundredth or the nearest tenth of a load factor. I suggest that the design load-factor be the nearest tenth of a load factor above the figure resulting from the use of the formula. For acrobatic types the high-angle-of-attack load-factor should be based upon the ability of a pilot to remain in possession of his faculties when subjected to heavy accelerations. As suggested by the author, more data are needed on this point, but for the present a design load-factor of 15, instead of 16 as he proposes, should be adequate.

Safe Pull-Out Speed

For one design condition for the tail surfaces, the author proposes that a diving speed, which I have called the safe pull-out speed, be computed from the stalling speed of the airplane and the high-angle-of-attack factor divided by the desired factor of safety. After finding the tail load required to obtain balance, the airplane being assumed to be at the angle of zero lift, an additional load is superimposed to allow for the load on the elevators. As the author states, this procedure would result in the design of a tail having a strength that is comparable with that of the wings in a sharp pull-out from the speed in question. In the paper mention of the safety factor at this point is omitted but that probably is an oversight. If the author were to compute the safe pull-out speed by multiplying the stalling speed by the square root of the high-angle load-factor, he would obtain a velocity about 23 per cent greater than the safe speed from which a sharp pull-out could be made, as the speed he would compute would be the one from which a sharp pull-out might produce an imposed load-factor equal to the design load-factor for high angle of attack. If the tail were designed for this load, both tail and wings would be at the breaking point in a pull-out from this speed, while both would have a factor of safety of 1.5 at a speed 19 per cent slower. Dividing the high-angle-of-attack load-factor by the safety factor when computing the safe pull-out speed, and then multiplying the load on the tail at this speed by the safety factor to obtain the design load is a better method. Thus, one of the intermediate figures would be the maximum speed of dive from which a sharp pull-out could be made with the factor of safety of both tail and wings equal to at least 1.5. This safe pull-out speed could then be posted in the cockpit for the guidance of the pilot.

If the safe pull-out speed were sufficiently high to be used as the maximum allowable-speed, designing for the low-angle-of-attack condition would be unnecessary, as the possible load on the rear spar would never be greater than that in the high-angle-of-attack condition. This is shown by the curves in Fig. 6 and similar curves in my book on airplane design[16]. The author shows clearly, however, that we must design for a pull-out in which the maximum lift-coefficient is not encountered but fairly large accelerations are produced in connection with relatively low values of the lift coefficient. His discussion of this point has been confined to the small acrobatic type of airplane but it applies with equal force to large commercial designs. A design that could not maintain level flight at twice stalling speed would hardly be considered satisfactory at present, yet a sharp pull-out from twice stalling speed will result in an imposed load-factor of 4.0. If we apply a factor of safety of 1.5, the required design load-factor would be 6.0. Thus, if the maximum allowable-speed were held down to that at which level flight could be maintained and the design load-factor set at the maximum that could be imposed at that speed multiplied by a safety factor of only 1.5, the high-angle-of-attack factor would have to be in excess of 6.0 for all commercial designs, whereas experience has shown that for many designs a design load-factor of less than 6.0 is adequate.

More test-data are needed to formulate a truly rational basis of design and instructions to the pilot regarding the limitations he should impose upon himself in pulling out of dives at speeds greater than the safe pull-out speed. The use of a low-angle-of-attack load-factor equal to 70 per cent of that in high angle of attack and an attitude corresponding to level flight at twice stalling speed has worked satisfactorily in the past, and these figures may as well be retained until further information is available. In his discussion of this phase of the problem, the author appears to advise some modification of the definition of the low-angle attitude, but this seems unnecessary unless the maximum allowable-speeds obtained in back-figuring from the low-angle factor turn out to be much lower than speeds that experience indicates to be necessary in practice. If this should prove to be the case, the lift coefficient for a low angle of attack could be defined as less than 25 per cent of the maximum lift-coefficient.

In discussing the required loads for tail surfaces, the author lists the required balancing-load in a dive at the maximum allowable-speed as one to be considered. As the maximum allowable-speed will be greater than the safe pull-out speed, this load may be greater than the balancing load at the latter speed plus the extra elevator-load proposed. Some additional load should be computed as representing the elevator effect, though the coefficient would be smaller than in the latter case, as the assumed pull-out would be an easy instead of a sharp one.

One factor of the problem that has not been discussed by the author is that of giving the pilot warning when he is approaching the strength of the structure while flying his airplane. The author proposes that a maximum allowable angle-of-attack be specified for easy pull-outs from dives at terminal velocity in acrobatic airplanes, but telling the pilot that he must not exceed an angle of say +2 deg. in such a maneuver would be futile, as he has no means of knowing what the angle

[16] See Airplane Design, by Alfred S. Niles, vol. 1, p. 204.

of attack is during flight. Prof. Elliott G. Reid proposes that an accelerometer with a red line to show the maximum allowable load-factor should be placed on the instrument-board. Such provision appears practicable, but having the red line at a point determined by the high-angle-of-attack load-factor would not be safe, as the pilot might impose the load in a low-angle attitude in a pull-out from a dive at terminal allowable diving-speed and the position of the danger line should be determined by the low-angle load-factor. The pilot could then be told the safe pull-out speed and the allowable diving-speed. His instructions would be that, so long as his speed was lower than the safe pull-out speed, he might pull up on the stick as hard as he wishes, but that when flying at a greater speed he must not pull up so violently that the indicator on the accelerometer would rise above the red line. The pilot would soon learn the correlation between his physical sensations and the accelerometer readings and thus become thoroughly acquainted with the possibilities of his airplane.

I hope that the discussion of the paper will result in a revision of the present rules for computing load factors. The small changes in the high and low-angle-of-attack load-factors he recommends would put them on a more rational basis and pave the way to still more rational figures when the accumulated data warrant another change. This, however, is not as important as a revision of the rules for the nose-dive condition and the tail loadings which now have no relation to the loadings for the other conditions. By adopting either the author's suggestions or some modification of them, obtaining such a connection would be possible, and thus the weakest point in our design loadings would be corrected and the rules put on a basis that would be much more rational than that used at present. Such changes, however, would be only a single step toward the goal and every encouragement should be given to those who, by accelerometer and pressure-distribution tests, are collecting the data required for further intelligent revision of our design rules.

Piloting Technique the Principal Factor

RICHARD V. RHODE[17]:—Several facts about load factors have always seemed clear to me; (*a*) we can roughly classify or graduate load factors according to the function of the airplane, (*b*) the manner in which the pilot exercises that function determines the load factor in a particular functional group more than any other single influence and (*c*) outside of a few elementary formulas that may or may not have real significance, we know very little about the whole subject.

With respect to (*a*), that fighting airplanes are subjected to higher accelerations or applied load-factors than transport airplanes is certainly well known. This is true, not primarily because the latter are inherently more sluggish or less maneuverable than the former, but because pilots simply are not required, and do not attempt, to do the things with that type of airplane which they do with the fighting craft. In other words, function determines that the load factors in one case are low, and in the other, high. The types mentioned are, of course, on opposite ends of the function scale. Other types, however, could be mentioned which come between these extremes. To avoid too fine a subdivision, functional groups probably should be placed in categories such as acrobatic, semi-acrobatic and non-acrobatic. Drawing too fine functional distinctions would be foolish but they should, nevertheless, be taken into account directly in accordance with the general principles now in use by the Army. This may be an arbitrary procedure but a perfectly logical one. To conceive that a formula, even one based on gross weight and power loading, could ever properly replace the function scale is difficult.

Differences in psychological make-up or temperament, physical build, nervous reflexes and similar characteristics of the pilot will all assert themselves. Some recent tests by the National Advisory Committee for Aeronautics and the Navy at Langley Field showed that several pilots, in attempting to execute the same maneuver, obtained a variation in load factors on one airplane which was twice as great as the maximum difference in average maximum load-factor for three airplanes having markedly different sensitivities to given control movements. Differences in the qualities of maneuverability of these airplanes had a sufficiently marked influence to justify taking them into account in some way, but the differences in piloting technique were so great as to subdue the other influences almost entirely. I think I may say, without violating any confidences, that in these tests, which had to do with pull-outs from approximately vertical dives, the differences in load factor between the three airplanes did not correspond qualitatively to differences in the quantity $(V_t/V_0)^2$ but rather to some more or less elusive quality of maneuverability, even though the pilots did not, by any means, make full use of the control power available. The accelerations obtained in these tests seemed to depend on the outcome of a rather delicately conducted contest between airplane and pilot, in which the airplane strove for high accelerations and the pilot tried to keep them to a reasonable level. The scores varied according to the relative skill of the pilots, just as in any game of skill, and showed a tendency to be somewhat higher or lower for the different airplanes, according to whether the game required more or less skill.

Of course, the foregoing illustration deals only with a special case, the pull-out of the steep dive, but in other cases, too, the technique of the pilot, or the manner in which he handles the airplane to exercise its proper function, is important. Even in the case of transport airplanes, which need only to be guided to a given destination, my observations lead me to believe that some pilots will cruise along in bumpy weather at low altitudes while others will attempt to find some smoother air strata.

Piloting technique cannot, of course, be included as such in any load-factor scheme, but its influence must be thoroughly studied with accelerometers before any satisfactory conclusions as to probable applied load-factors in the different categories or functional groups can be drawn. Until this is done, I am afraid that paying too much attention to the characteristics of the airplane is somewhat unwarranted. These characteristics have only a secondary influence and, while they should not be neglected, they should be considered only after the more important irrational factors are understood.

The rational process can be applied, however, to other than the load-factor phase of the design procedure. For instance, once a load-factor scheme has been set up and certain characteristics of the airplane, such as speeds, wing profile and wing loading, are known, a rational correlation of the load factor with such things as tail-load and wing-load distribution is entirely possible. Recently the trend has been in this direction, and I think more should be done along these lines.

In conclusion, I would like to call attention to a minor point in Prof. Newell's paper, which states that the dive load acting upon the rear spar at terminal or limiting velocity may exceed the corresponding loads in low angle of attack, so that the latter condition can be eliminated for conventional biplanes. This possibility has been brought to my attention before, and I think this is a good occasion to discuss it briefly. Munk has

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shown theoretically, and this has been verified by numerous tests, that the load on a wing consists of a moment equal to $K_{mo}c\,S\,q$ and a force, equal to $C_L S\,q$, which acts at a constant point of application near the quarter-chord point. For conventional airfoils, the moment coefficient K_{mo}, which is a function only of camber, is negative or in the diving sense and gives rise to rear-spar loads that act approximately in the positive Z or upward direction. Furthermore, the portion of the rear-spar load caused by the moment coefficient remains constant on any airplane provided that the dynamic pressure or air speed remains constant. On the other hand, the lift force $C_L S\,q$ increases with increasing angle of attack, and, since it acts at a constant point of application that lies between usual front and rear-spar locations, it gives rise to upward-acting rear-spar loads that always increase with increasing angle of attack as long as the air speed remains constant. That no appreciable loss of air speed occurs in passing from the dive to the condition of maximum acceleration in the pull-out has been amply verified. We have, then, on any given airplane in a pull-out, a partial rear-spar load that remains constant up to the critical point in the maneuver plus a partial rear-spar load that progressively increases from zero, at zero lift, to the maximum when the critical point is reached. The rear-spar load is, therefore, always greater in the critical low-angle condition than it is in the dive.

Author's Closure

JOSEPH S. NEWELL:—The discussion evoked shows the diversified points of view from which various engineers who are immediately concerned with and who have given thought to this problem regard it. Mr. Gazley sees the proposed formula as a step in the right direction, but he considers too much weight to have been given the horizontal-surface constant and proposes a simpler expression in which a single empirical constant provides for everything but the speed range. He also recommends various means for improving the charts used for estimating speeds, improvements that are very desirable and much needed. Too much importance has, perhaps, been given the horizontal-surface constant in the proposed formula, but studies now being carried out at the Massachusetts Institute of Technology and by engineers of one of the aircraft manufacturers interested in this problem both indicate the impossibility of pulling large airplanes from low to high angles of attack at high velocities due to the damping effects produced by long tails. A condition of equilibrium is reached on a large airplane, for a given position of elevator and stabilizer and a given force exerted by the pilot, at an angle of attack much below that of maximum lift, and studies on geometrically similar airplanes seem to indicate that the length of the tail is the variable having the greatest effect on the maneuverability of airplanes of different sizes. Mr. Gazley's suggestion that a coefficient depending upon gross weight would provide for this effect is correct so long as airplanes of different sizes remain geometrically similar, as they are at present.

Lieutenant MacCart and Mr. Rhode both feel that the low-angle-of-attack condition is of primary importance if design requirements are to be scrutinized and changed. Both seem to base their conclusions on the relative magnitudes of the lift components on the spars at various attitudes and to overlook the drag components that often produce axial loads in the spars, particularly the lower rear spar of a staggered biplane, of sufficient magnitude to render a design condition involving a smaller lift-component but a larger drag critical for the design of the wing spars. In my opinion the low-angle-of-attack conditions proposed by them do not give sufficient consideration to the effect of drag components from the wings and the interplane bracing on the axial loads in the spars. Both Rhode and MacCart emphasize the importance of accelerometer studies to determine the physiological resistance of the pilot which is, after all, the upper limit for which designers must provide and hence is the most important phase of the problem of evolving load-factors that will prove satisfactory.

Professor Niles' comments agree, in the main, with my proposals and suggest means for improving them. His recommendation that an accelerometer be made a part of the standard instrument equipment is worthy of consideration as present-day pilots have but little idea of the magnitudes of the loads to which they are subjecting an airplane. If the incorporation of an accelerometer into every instrument board appears too drastic, might it not be well to equip training airplanes with such instruments and require a certain amount of accelerometer flying to be done by each pilot before he is licensed, with more to be done each year that he holds a license? Some method should be devised for educating pilots regarding the magnitudes of the forces they impose on airplanes in various maneuvers and a procedure of this sort seems both practicable and rational.

I wish to thank those who contributed to the discussion of this subject. My desire was to provoke a discussion and to arouse interest in the problems of rationalizing load factors, rather than to present a solution of any of them, and if the interest that has been aroused can but be continued until a more satisfactory solution than the present one has been found, I will feel that my efforts have been well rewarded.

The Diesel versus the Gasoline Engine

LACK OF CONFIDENCE in the Diesel engine has existed as it did in the early days of the gasoline engine, but as the public has become better acquainted with this type of prime mover and the surprisingly long non-stop runs that have been made by it, a change in this respect has been noticeable. Operators of Diesel-powered equipment are becoming more numerous each year, and it is becoming apparent to those who have even a small knowledge of such equipment that this engine is not so complicated and mysterious as was at first believed.

Two of the most troublesome parts of the gasoline engine have been eliminated; namely, the carbureter and the magneto. In place of these has been supplied a simple single-acting plunger pump. Development of the disc type of strainer, by which the fuel can be filtered down to 0.0015 in., has made possible the overcoming of any troubles arising from small particles of dirt in the fuel.

Volatility of the fuel is not nearly as important as is the viscosity; it is absolutely necessary to have fuels that are sufficiently fluid to flow freely at the atmospheric temperatures in which the engine is operating.

The practice of our company is to rate its Diesel engines at the load at which they will operate continuously 24 hr. per day and 7 days per week and still have enough reserve to take care of adverse conditions. This cannot possibly be the maximum power that these engines will produce for short periods. A tendency among gasoline-engine manufacturers is to specify that, for continuous service, a load factor of not more than 85 per cent of the power shown on their torque curves should be used. This point has an important bearing on the price relationship between the gasoline and the Diesel engine; it tends substantially to reduce the differential that exists when comparisons are made on a price-per-horsepower basis.

As quick acceleration can be secured with a correctly designed Diesel as with the gasoline engine.—T. M. Robie, Diesel-engine division, Fairbanks, Morse & Co., in discussion at a meeting of the Cleveland Section.

American vs. European Aviation Development[1]

IN ALL OF EUROPE, nothwithstanding all the talk one hears of European aviation, there are only three airports that we need to look at with anything akin to envy. These are Tempelhof, in Berlin, because of its admirable location, the city entirely surrounding it, so that one can get from the center of the city to the field in 15 min.; Croydon, near London, because of its excellent hotel accommodations; and Le Bourget, because it is so near Paris.

In favorable contrast, we have the airport at Tulsa, Okla., which has more air traffic in the summer months than any other airport in the world; the airport at Chicago, with its excellent modern equipment; the airport at Oakland, Calif., and the Grand Central Air Terminal at Los Angeles, which have hotel accommodations rivaling those at Croydon; and the Detroit Municipal Airport, which has the largest hangar in the world and is very accessibly located. These are not, like Tempelhof, Croydon and Le Bourget, particularly outstanding among American airports but are merely representative. A survey of the airports in the central part of the United States in 1930 showed that there were 572 active airports, 118 of which were first class. In the East there probably are as many more, and very likely an equal number in the West.

Distances in Europe, especially international distances, are small and the light airplane is very popular. This has led to the formation of numerous flying clubs. The Aero Club of Rotterdam is one. In England the Heston flying-field is entirely supported by the privately owned planes kept there. Many schemes, other than government subsidy, are employed in Europe to increase the revenue at flying-fields. For instance, at many of the fields, especially in Germany, any pilot who lands is required to pay a landing fee. Everything on an airport must be paid for.

The Dornier Do-X, the largest airplane in the world, did not fly satisfactorily with European engines and was equipped with 12 American engines preparatory to a transatlantic flight. With the new American Curtiss engines now installed, the performance of the ship is greatly improved, due to the increased horsepower, the increased propeller efficiency resulting from a 2:1 reduction gear, and the smaller frontal area. The total weight was increased only 50 lb. per engine, or 600 lb. This includes the additional weight of radiator, tubing, cooling liquid, and so forth, necessary in changing from air to water-cooling. That additional weight in a plane of this size is almost negligible.

The often reiterated statement that "European airlines are better organized, better equipped and better operated than our own" is not true. One of the best known of the European airlines is the Imperial Airways, which operates planes daily between London and Paris. It owned in 1930 a total of 15 airplanes, all of which were old; a very liberal estimate of their combined value is $500,000. Western Air Express, in this Country, spent $600,000 in the spring of 1930 solely for *additional* airplanes to take care of increased passenger traffic between San Francisco and Los Angeles. The airplanes used on Imperial Airways have a cruising speed of 85 m.p.h., whereas the average cruising speed on airliners in this Country is more than 110 m.p.h.

The European airways do very little night flying, much less than we do. Although radio direction-finding is used on the better organized lines, it is the type in which the pilot sends out a signal which must be triangulated by ground stations, coordinated by them, and the pilot notified before he knows his position. In this Country our pilots are in continuous touch with ground stations and, by means of either the aural or the visual type of radio beacon, are able to stay exactly on their desired course.

The largest land planes I saw in Europe carry 18 passengers, whereas one of our airlines is operating 32-passenger planes. It is true that a 40-passenger four-motor Junkers plane has been built in Europe, but it is still in the experimental stage. A large percentage, if not the majority, of the people who ride on European airlines are American tourists, who, I suspect, often decline to ride on the far superior American lines.

Although we have overtaken and surpassed Europe in commercial aviation, the major European powers are rapidly threatening our supremacy in military aviation. For many years our military planes, although fewer in number than those of other great powers, have been the best in the world from the point of view of performance and general military efficiency, but in recent years there has been slight improvement in our bombardment, observation and pursuit planes. England, France, Italy and even Germany have improved their military planes during this period. Their more rapid development probably is due to the fact that they continued international racing. Every lesson learned in increasing the speed of racing planes is directly applicable to military planes, and, to a somewhat less extent, even to commercial planes.

While racing is not necessarily the most economical means of improvement, it does furnish an incentive to and an interest in development work. It is clear that, if we are to maintain our military supremacy in the air, we must devote a great deal more thought, energy and money than we have been doing in the past to the improvement of our military airplanes.

[1] From an address presented at a meeting of the Detroit Section by James H. Doolittle, manager, aviation department, Shell Petroleum Corp., St. Louis.

Inventory Control

Production Meeting Paper

By C. B. Stiffler[1]

PROVIDING ample stock to guard against the possibility of the interruption of production for lack of material was the chief aim of inventory control in 1920. Recognition of the importance of turnover is one of several factors that have led to a study of minimum stocks. Inventories received first consideration in the now well-established financial-control policies of the General Motors Corp. Formerly, placing orders for materials far in advance of needs had been thought necessary to assure the supply, but restricting orders to suppliers to three months in advance has been satisfactory for 10 years. Each car division of the Corporation now submits a definite monthly forecast, based on 10-day reports from dealers of stocks and actual and estimated sales, which estimates the number of cars to be sold by the dealers, delivered to the dealers and manufactured during the current and three forward months. Acceptance of this forecast is authority for the division to proceed with manufacturing and with procurement of material according to it.

In place of large stockrooms, a limited space is assigned for stock near each point where processing begins. The plant is now zoned, with an experienced man in charge of stock in each zone who has little use for any record except a shortage report showing what items need attention. The efficiency of handling has been improved until a supply for three days is normal now. Minimum banks of processed parts are also maintained. An example of the speed of handling is that a carload of frames loaded in Milwaukee on a Thursday afternoon arrived in Pontiac on Friday morning, were assembled into automobiles and a carload shipped Friday afternoon to Milwaukee and delivered to retail purchasers on Saturday afternoon.

Capital employed in inventories and buildings to house them now is estimated to be 25 per cent of what it would be if no improvement had been made in the last decade, and the cost of moving material is only 20 per cent of the former cost. Charts presented with the paper show the inventory investment and inventory turnover of the General Motors Corp. from 1920 to 1931.

Hearty approval of inventory control, as outlined in the paper, is expressed by one discusser who represents a supplier of parts. He also stresses the necessity for cooperation between car manufacturers and parts makers, stating that the latter should not be required to carry large stocks nor perform miracles to satisfy unreasonable and unexpected demands from the automobile plants.

Another point discussed at some length is whether the vendor has kept pace with the car manufacturer in determining how far he can reduce his forces and yet maintain a flexible organization to fill orders promptly. In this connection the experience of a supplier of crankshafts, who reduced his set-up time 75 per cent by using electric lift-trucks, is cited.

Adjustment of orders to meet fluctuations in car sales, whether one or several plants should supply a particular part and advantages of inventory control as enabling changes to be made quickly to correct defects or incorporate improvements are also discussed.

UNTIL a few years ago a warehouse full of unfinished stock, all paid for, was pointed to by the managements of many organizations with considerable pride and was generally accepted as one of the indications of a successful business. Perhaps the automobile industry was not guilty of boasting of its large inventories, but the fact cannot be disputed that until the last decade the general practice in the industry was to carry stocks of materials far in excess of current production requirements. In these last few years the attitude toward inventories has changed entirely, to the extent that abnormal inventories are frowned upon by everybody including the banker. While the change was partly due to the recognition of turnover as a factor in modern business, other influences of a more compelling nature were mainly responsible.

Material Practice in 1920

The change in attitude has been so pronounced in our own business that looking backward a few years and trying to determine why we formerly carried such large stocks of materials in the plant was interesting. In a procedure governing the procurement and movement of material, developed in 1920 by one whom we still recognize as an authority on such matters in General Motors, production was very clearly indicated to be the important thing, and the point that every precaution must be taken to have sufficient material on hand to maintain that production was emphasized. Then the accepted method for assuring continuous production from a material standpoint was to have a large quantity of each item of material on hand in the plant. The instructions in the procedure governing the stocks of materials in the plant have to do entirely with maximum stocks and state, for example, that

> This maximum should be sufficiently large to have the follow-up department feel justified in notifying the source of supply to curtail on future shipments.

Apparently such a thing as minimum stocks received no consideration whatever. A further suggestion is made in the procedure that purchase requisitions be placed months ahead of the actual receipt of material. This is interesting when compared with the now generally accepted practice in placing orders for future material requirements with suppliers.

Another interesting feature of that 1920 practice is

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the description of the use of the records. Without an actual comparison of the records required in 1920 with those required by our present practice, I would say that we then used 5 times as many forms and 25 times as many figures as we now use, despite the large increase we have since had in the volume and complications of our production. Of course, these 1920 methods would have been refined and improved upon through the years in the regular course of progress. However, the sad experience of industry in general and of the automobile industry in particular, resulting from the post-war deflation in 1921, clearly indicated the weakness of many of our methods and practices. The sudden change from post-war prosperity, when almost any kind of automobile could be sold at a satisfactory price, to the condition where the public stopped buying and automobile sales were difficult, even though prices declined sharply, resulted in the industry generally being caught with large stocks of material that had been purchased at inflated prices. The losses sustained in reducing the valuation of inventories to the current market prices, added to those sustained through cancellation of commitments with suppliers, clearly showed the necessity for a radical revision of our methods of material procurement and movement through our plants.

Until this time the production and distribution of our product was so important that very little consideration had been given to the business side. Recognizing that more attention must be given to the costs of carrying on the business if the individual companies of the Corporation were to fulfil the purpose for which they were organized, General Motors developed and adopted its now well-established financial-control policies, the explanation and operation of which have been so clearly and interestingly presented in a booklet by Albert Bradley, vice-president in charge of finance.

Importance of Inventories Recognized

In the development and installation of these financial-control policies, inventories naturally received first consideration since a very substantial portion of the losses sustained in 1921 was due to the cancellation of commitments with suppliers. On account of the rapid increase in the production of automobiles previous to 1921, the facilities of suppliers were taxed to the extent that engaging these facilities by placing orders for materials far in advance was believed necessary to assure the sources of supply. Convinced as General Motors was of this necessity, considerable courage was required to adopt the plan of restricting forward orders on suppliers to three months. The Corporation preferred to take the chance of not getting as much material as might be required rather than of having more material on order than could be used. This safeguard against commitment losses has been so effective that no changes or revisions have been made in the 10 years of its application. Certainly the suppliers are entitled to their share of the credit for the successful operation of this plan. They have made their deliveries as faithfully as before when they had orders for a year in advance.

The installation and the operation of the commitment control were much easier and the desired results were obtained more quickly than could possibly be done with the inventory control. Aside from the difficulties resulting from the movement of millions of pieces of material required to build thousands of automobiles monthly, the greater difficulty of knowing how many automobiles to build existed. The determination of future sales volume is a big problem in any line of business, and this is particularly true in our business, due largely, no doubt, to the size of the package.

Recognizing that a dependable method of estimating future sales was necessary for the successful determination of future material requirements, General Motors developed and adopted a monthly forecast of operations. Every month each car division of the Corporation submits a definite forecast that shows, along with other information, the estimated number of automobiles that will be sold at retail by dealers, the number of automobiles that the division expects to sell to the dealers and the number of automobiles to be produced by the factory to realize these sales. This forecast covers the current month and the three forward months. The key to the whole forecast is the estimated retail sales. Each car division receives from its dealers every 10 days, in addition to other information, the actual number of cars delivered to customers together with the stock of new cars on hand. A continuous record of this information of retail car-sales and stocks by periods over a number of years establishes reasonably accurate trends. The trends, used in conjunction with the knowledge of economic and other conditions prevailing, enable the retail sales for the forward three months to be forefast with sufficient accuracy to determine material requirements and production scheduling.

Acceptance of a division monthly forecast constitutes authority for that division to proceed with the production schedules indicated. The purchasing department immediately issues orders to suppliers for the material required to meet those schedules. Assume, for example, a production schedule of 10,000 cars for October and for each of the next three months, November, December and January. The materials required for November and December were already on order from previous months. The orders placed in October will cover the materials needed for January production.

Under this arrangement the maximum material on order at any time is the quantity required to meet the estimated production. Month by month this same routine is carried out so that each month's requirements are estimated three times. This, therefore, affords two opportunities to correct the previous month's errors in quantities and model types. The demand for various body types, such as coupés, sedans and roadsters, is difficult to anticipate and the schedule by types is almost sure to change even though the schedule of total quantities remains the same for two months or more in succession.

Deliveries of Materials

Accompanying the purchase order is the delivery schedule which directs the supplier to ship specific quantities on positive dates for the following month and also furnishes him tentative quantities and shipping dates for the two succeeding months. With this information the supplier is able to work out his own manufacturing program. The delivery schedule is the key to the successful control of the material flowing from suppliers to our plant. The quantities and delivery dates are determined after giving consideration to such conditions as distance between supplier and our plant, time required by us for fabrication, transportation facilities and the like. This scheduled flow of materials from suppliers eliminates the necessity of large stocks in our plant, since a sufficient quantity for immediate needs is all that is required, and this usually does not exceed three days' stock of finished parts purchased from suppliers.

As the 10-day reports from dealers are reviewed in the aggregate from period to period during the current month, they may indicate the necessity of an increase or a decrease in the production schedule to maintain the dealer stocks in line with the retail demand. Production is adjusted to the new condition and the suppliers are requested to accept a new delivery schedule of material which moves the material on order forward or

backward, as may be necessary to continue the even flow of material required to build the revised production schedule.

One of the most important, if not the most important, contributions to the successful operation on minimum inventories has been made by the men responsible for material inside the plant. They not only adapted themselves to the restricted ordering and delivery of materials from the outside, which came as a command from the management, but, after they became aware of the advantages of small inventories, their methods of moving materials inside the plant improved rapidly to the extent that they continually forced the minimum requirements lower.

While considerable has been accomplished in working out lower inventories outside of the material men themselves, my belief is that the material men inside the plant have really brought it down lower than anybody else. On a number of occasions I have heard them insist that the purchasing department should not order in as much material as planned. They did not need it, and what we call the "float" or the stock required or line leads has been reduced more by the material men themselves than by anybody else. Their interest, however, in the whole matter was originally created from an outside source or interest, but they really have pushed this line lead and this required stock down, and this new idea, in which we are all interested now, that the cost of handling materials is a part of overhead, has forced the material men to reduce their costs. One way in which they have accomplished this is by keeping a lower supply of materials, which requires less handling and less breakage.

Conditions in 1920 and 1930 Compared

The plant material organization of today is full of life and energy in contrast with its predecessor that was hopelessly weighed down with more materials than it knew what to do with and laboring under the dull, sluggish and uninteresting methods then in use. The simplicity of the routines for moving and controlling the materials within the plant is almost unbelievable when compared with the practices of 10 years ago. The elaborate records are gone and also the clerks that filled them out. The shop is no longer cluttered up with the material-control booths and the millions of operation tickets that went in and out of them. The stockrooms covering acres and acres are a thing of the past.

The plant is zoned now, with an experienced man in each zone who knows the materials for which he is responsible, how much he needs to meet the schedule, whether he has enough to meet it and, if not, where he will get the quantity he needs and when. About the only record for which he has any use is his stortage report, which shows him at all times just which of his material items needs attention. Instead of stockrooms, the zone material supervisor has sufficient space assigned to him to place his material near the particular processing operations until it feeds into production.

In addition to the credit we give suppliers for their assistance and cooperation in the reduction of inventories, we also recognize the contribution made by the transportation companies through their increased efficiency in moving the material while it is in their hands. A few years ago when we first began to develop a real interest in turnover we used this example to show what was being done:

> Our frames were purchased in Milwaukee and on Thursday afternoon a carload of them was loaded at Milwaukee and arrived at Pontiac on Friday morning. The frames were assembled into automobiles on Friday and a carload shipped to Milwaukee that afternoon. The automobiles arrived and were unloaded at Milwaukee Saturday morning and delivered to retail purchasers the same afternoon.

Other classes of inventory have been reduced correspondingly with the materials. Work in process formerly seemed to pile up for no particular reason, except that both labor and material were available in an inexhaustible supply. Nowadays, minimum required banks of processed parts ready for assembling and partly processed materials between operations are definitely established to determine the delivery schedule of material from suppliers. Were it not that the processing operations themselves are subject to schedule, these operations must stop for lack of material. This excess work in process is not possible under the methods now employed in our factory.

Finished automobiles are no longer looked upon as something that must, of necessity, run up the inventory values to staggering sums. While some companies still continue to warehouse large stocks of finished automobiles, others have adopted the practice of adjusting the car-assembly schedule to match the dealers' orders. Under this arrangement the total number of cars ordered for delivery each day are built according to types and moved off the line to the shipping dock. The individual dealers' orders are filled, loaded into box cars

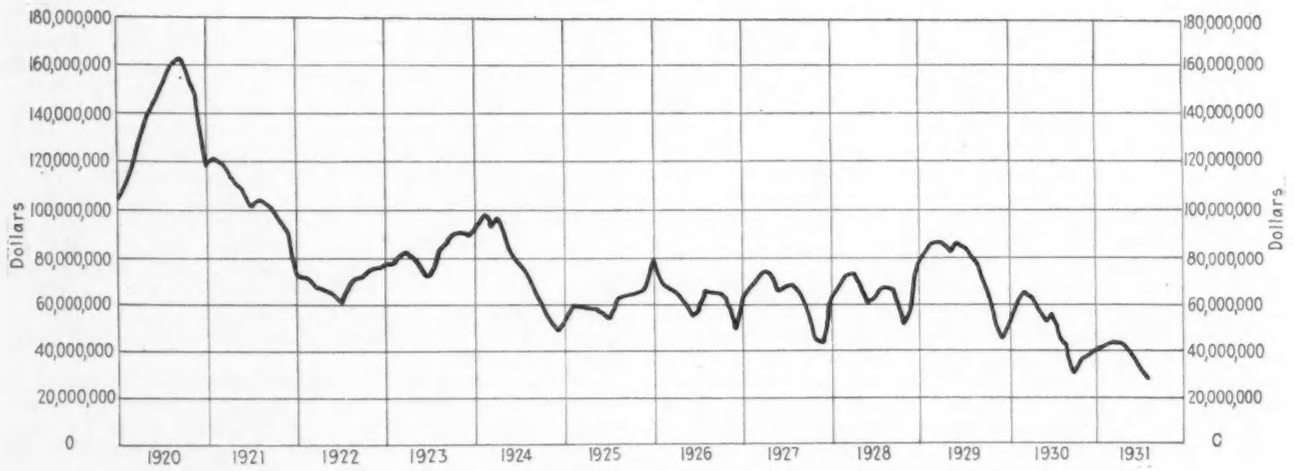

FIG. 1—CHART OF PRODUCTIVE-INVENTORY INVESTMENT

The Marked Reduction in the Maximum Amount from 1920 to 1929, Approximately 50 Per Cent with a 500 Per Cent Increase in the Number of Cars Sold, Was Made Possible by Inventory Control

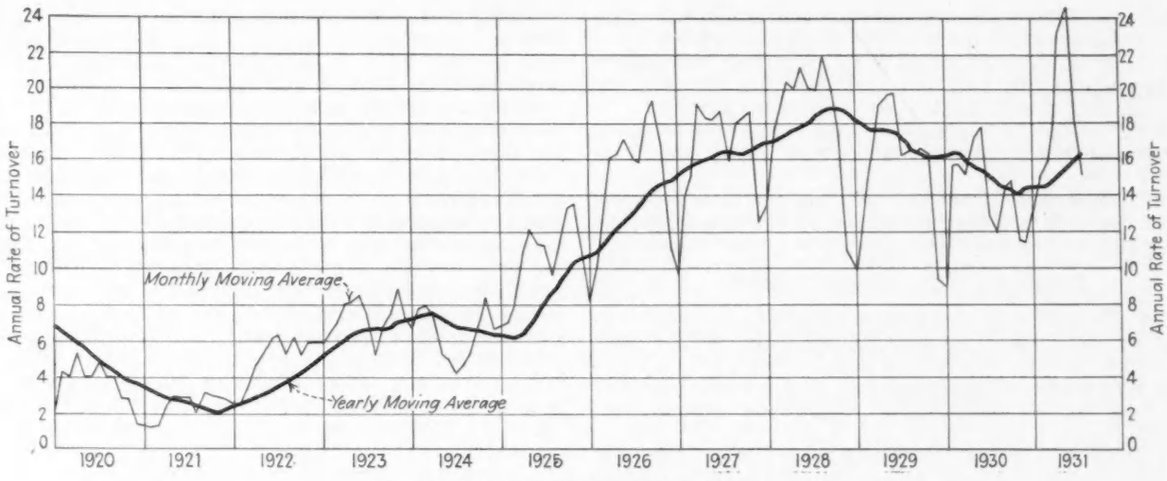

FIG. 2—PRODUCTIVE-INVENTORY TURNOVER

In 1920, Prior to the Adoption of Inventory Control, the Maximum Annual Rate was 6.75; in 1929, after 9 Years of Inventory Control, This Value Had Increased to 18.00

and shipped. No necessity exists for warehouse stocks beyond the number of cars required to fill the shipping orders for that day.

Benefits of Minimum-Inventory Operation

The good effects resulting from the operation with minimum inventories are so numerous that to separate and name the more important ones in the order of their importance is difficult. If we should say that the greatest benefit is the one that reaches the greatest number, then surely the most important results have been those that had the greatest effect on reducing the price of the product to the public. The cost of moving material now is conservatively estimated as 20 per cent of the former cost. The capital employed in inventories and the buildings to house them is now 25 per cent of the amount that would be required if no improvement had been made over the previous decade. Cost and employed capital are two important price factors, and, therefore, these reductions have been of great benefit to the public in lowering prices.

The business itself has shared in these benefits in increased facilities and capital when needed. Likewise, the owners of the business, the stockholders, have received increased returns on their investment. Suppliers and their labor have enjoyed with us and our labor a better distribution of labor itself. Dealer losses sustained in moving distress merchandise have been reduced to the minimum, and our dealers experience lessened sales resistance by the opportunity afforded the manufacturer to meet competitive changes in the product in much shorter time. Certainly the control has accomplished its original purpose of preventing large commitment losses as well as those excessive losses arising from shrinkage in material values.

To clinch the argument, if any argument exists, that the inventories required are smaller and the turnover rate improved, General Motors has permitted me to use its charts for the years 1920 to 1931, inclusive. Fig. 1 shows that, in 1920, when the Corporation sold 393,074 automobiles, a maximum productive inventory, not including finished cars, of $163,000,000 was required. In 1929, when the Corporation sold 1,899,267 automobiles, a maximum productive inventory of $83,000,000 was required. The highest point of the turnover of productive inventory in 1920, as shown in Fig. 2, was 6.75 and in 1929 was 18.00, indicating the inventory turned 6.75 times in 1920 and 18 times in 1929.

THE DISCUSSION

JOSEPH H. MOORE[2]:—How frequently does Mr. Stiffler adjust the releases for shipment sent to the supplier?

MR. STIFFLER:—We would not change the shipping schedule for the next forward month, for example, November, until we were in that month. About Nov. 15 we might find that the retail sales were not coming through as we anticipated. That would bring into our plant more materials than we would want, because we naturally would cut the production schedule. Then we would go back to our suppliers and ask them to slacken their production. We always endeavor to be reasonable about that. We do not intend to work any hardship upon the suppliers at that time, but we do ask them to curtail production, which will bring less material into our plant in the second half of November.

We consider that only one adjustment per month is reasonable. Perhaps we have made more than that, but as a usual thing, no.

MR. MOORE:—What would you consider a reasonable fluctuation in your production schedule before you ask your supplier to change his schedule?

MR. STIFFLER:—I should say nothing less than 25 per cent of the month's schedule.

MR. MOORE:—Within the 25 per cent you would let the outstanding schedule stand?

MR. STIFFLER:—I think so, in fairness to the supplier.

J. L. JUHL[3]:—Twenty-five per cent makes a pretty tight squeeze on inventory if you get 18 to 19 times turnover per year.

MR. STIFFLER:—This is what I mean. I used an example of 10,000 cars in a month, which assumes that we have materials on order for 10,000 cars for November. If we found on Nov. 15 that we would sell only 7500 cars to our dealers, we would ask our suppliers to hold up 2500 sets of material. If we saw that we

[2] Manager of stores record department, Hudson Motor Car Co., Detroit.

[3] General superintendent of planning division, Murray Corp. of America, Detroit.

would sell 8000 cars, we would not change our shipping schedule; that would be too small an amount.

MR. JUHL:—Assuming that the schedule was 10,000 for the month, and you found between the 10th and the 20th of the month that your sales requirements, instead of being 10,000, were actually 12,000, how much over the 10,000 do you go before you notify your suppliers?

MR. STIFFLER:—If we see that we can produce even 11,000, we will ask our suppliers to get the materials for us if they can, and we nearly always get them.

What Is a Three-Day Bank?

F. A. UPTON[4]:—If you have a three-day bank of material on hand, why do you get only an 18 per cent turnover?

MR. STIFFLER:—Because so many other materials that have been in the plant longer than three days are included.

MR. UPTON:—Then the purchased parts from the suppliers are run at the minimum and your manufactured parts are run heavier than that?

MR. STIFFLER:—That is very likely.

MR. UPTON:—So your total inventory runs only 18 per cent?

MR. STIFFLER:—That is probably true.

MR. UPTON:—Eighteen times turnover in a year. What proportion of the products in your organization is purchased and manufactured? Do not you find your purchased parts running heavier than your manufactured parts?

MR. STIFFLER:—I cannot say offhand.

MR. UPTON:—I have always heard about this three-day stock of parts of the supplier. I have visited a number of plants and never yet found the three-day stock. I want to get some light on just what this three-day stock is. If you get a 25 per cent increase in your schedule, my experience has been that it will catch up on you before you can obtain new material.

MR. STIFFLER:—No, I do not think so.

CHAIRMAN V. P. RUMELY[5]:—That is modified by how soon you increase your schedule.

MR. STIFFLER:—Mr. Upton is assuming that an increase in schedule occurs immediately, whereas it does not. We draw on that three-day supply and may use it up, but we then have an additional day or two to draw on. We have considerable purchased material that is in the plant longer than three days, but we work everything that we can on the three-day schedule.

MR. UPTON:—I understood average, is that right?

MR. STIFFLER:—No. We would not have an average of purchases because we purchase material hundreds of miles away. We could not work entirely on a three-day schedule, but we aim to have a three-day supply of stock in the factory as the minimum, although we may have a 10-day supply of carbureters or 15 days of something else. We have many purchased parts of which we do not have any more than three days' stock.

MR. JUHL:—What is the method of distinguishing what shall be three days, price entirely or distance from the home plants?

MR. STIFFLER:—How hard or how easily we can get the part. Price has nothing to do with the question, except that we buy standard parts, screws, nuts and bolts and that kind of material by the million. They do not amount to anything in the inventory anyway. We do not worry about those; neither do you.

CHAIRMAN RUMELY:—Mr. Juhl, what banks of material ahead of the first operation do you try to maintain at Murray Corp.?

MR. JUHL:—A three-day bank as nearly as possible, but unfortunately we are not in such a comfortable position as the automobile manufacturer. We are lucky now, with the way we are getting orders from our customers, to be able to have enough to keep a line going. You car builders are all depending upon your vendors to take care of you at the least call. As a result, we find ourselves out scurrying for material very much harder, I believe, than the average automobile company, because bodies are not ordered, as a general thing in our experience, until the sale is actually made, and we find that we get very short notice. Some of our customers, in fact, give us an order for 1000 bodies on a certain day in the month and expect delivery of the finished bodies in three weeks. That is not giving us much chance and we have many such instances.

MR. STIFFLER:—The inventory which I gave you was that of the General Motors Corp., not the Oakland Motor Car Co. This includes all of the accessories and everything else.

I did not intend to convey the impression that all of our purchased finished parts are on a three-day basis, because that it not true; I was trying to point out that we insist on having at least a three-day supply of every part in the plant, and we have no more than that of a great many. Tires are very readily available, and we do not have to carry a large stock. We get them from Detroit, and they are shipped by truck.

Views of a Parts Maker

J. E. PADGETT[6]:—At present, to a great extent, the parts maker is carrying the automobile builders' inventories, or he puts himself in a flexible enough condition so that he can meet all kinds of demands. With the conditions as they are at this particular instant, particularly with so many new models coming out and plants operating at low production, we reflect that condition, and the only economical way of operating a plant under those circumstances is a week on and a week off, three days on and three days off or whatever schedule a particular manager feels is best suited to his conditions. We would likewise prefer to run a week on and a week off, but we cannot do it.

About five minutes after I had instructed one of our plants to close down for a week, a call came from a big motor-car company for 5000 shafts. Therefore, we started a mass of machinery and heat-treating installations with excessive non-productive labor because of putting a limited quantity through, which increases our costs tremendously. In the long run the car manufacturer and the public are paying for that uneconomical processing; so that proper economical inventory control has some limits.

MR. STIFFLER:—Is that condition any worse than it was 10 years ago when you were allowed to pile up your orders and shut your plant down for three weeks while the automobile factories were using up those parts?

MR. PADGETT:—In our particular business my province is trying to forecast what our customers will use. We are such a broad supplier to the industry that we are in contact with almost all of the automobile and truck makers, and the only way in the world that we do it is to try to outguess them. No statistics are available and we just try to figure out what will happen and be prepared for it. We must be, because if we are not, we shut their plants down, as they have a three-day stock on hand and cannot wait. I am not complaining. I only want to impress on those who have this in their control in automobile plants that, in the long run, making us work uneconomically costs them money.

MR. STIFFLER:—Undoubtedly conditions are wrong somewhere, but I think you will admit that anything which brings the consumer closer to the original producer ought to be beneficial.

[4] Materials supervisor, Dodge Bros. Corp., Detroit.
[5] M.S.A.E.—Factory manager, Hudson Motor Car Co., Detroit.
[6] M.S.A.E.—Assistant general manager, Spicer Mfg. Corp., Toledo.

MR. PADGETT:—That is entirely true. Probably the finest thing which has been done is that General Motors tries to give more or less specific forward information, which it endeavors to stand back of and on which a parts maker can work. If he wants to, he can produce the material two weeks ahead and make shipments as required, but everybody does not do that. If they would give us information for two weeks in advance and stick to it, that would be fine, but we do not get that. We get one of two days' notice, or as Mr. Juhl said, he gets three weeks' notice on a body that may take six weeks to process and that is what hurts.

MR. STIFFLER:—We have undoubtedly been guilty of that, but in the last few years we have improved our practices considerably. Our company used to be wild on forward orders several years ago, and I know that it worked a hardship on the suppliers, but I do think we have remedied that condition year by year. Any of our suppliers will admit that matters are much better than they were formerly. The fluctuation in the operation of a supplier's plant is much less now than formerly. Of course, we are a long way from perfection yet, but I do think we are improving.

MR. MOORE:—I do not believe Mr. Stiffler has touched on the effect of inventory control on the engineering department with relation to changes.

MR. STIFFLER:—No. I only mentioned that it places us in a better competitive position or rather places our dealers in a better competitive condition. The thought I had there was that the smaller the quantity of material is that we have on hand, the sooner we can make an effective engineering change.

MR. MOORE:—You find that it does work to advantage in that respect?

MR. STIFFLER:—Yes, for a plant to be able to put a competitive change into effect at once, without a large material loss, is very important, but I mentioned this as a benefit to the dealer rather than to the company, because we are then able to put him in a competitive position to sell.

Has Vendor Kept Pace with Manufacturer?

A MEMBER:—In reply to Mr. Padgett's statement regarding the small opportunity the vendor has of governing his production because of last-minute calls from some large manufacturer, sales govern the whole question. In the larger companies, such as General Motors and Chrysler, the scheme has been worked out very closely, as regards maintenance, engineering and all our other burdens, to take care of it at the times when the plants are shut down and to reduce the number of men in the plant at that time.

To start up some small department, the vendor must bring in a certain number of maintenance men and men who are employed in other departments which are functioning precisely the same as though the plant were running at practically one-half or two-thirds of the normal operating time.

Have the smaller vendors kept pace with the larger manufacturer, have they made an intensive study and have they investigated carefully to see how closely they could shave and still leave themselves flexible enough to be able to supply at demand the people to whom they cater? As we see it, and having gone through these last six months with our production where it is all unseen, we are looking forward and expecting orders and at the last moment, when everything is prepared to shut the plant down completely or for a few days, production has made a little spurt and we have had to reach out quickly and say, "Well now, how fast can we get this material in?" The little producer, as he says, is ready to supply, he is called on to operate or otherwise he will tie up the manufacturer. I answer the question in this way:

Did he keep pace with the larger manufacturer in trying to make his production flexible, and did he pare down to the point where he will not have to bring in the unnecessary burden to help produce the smaller articles which he is called upon to furnish?

MR. PADGETT:—We would not operate at all if we could not do so at less than the car manufacturer who is our only source of business. We do not have a product that is distributed more or less generally to a public which buys what we make. We have a product that is made specially to the engineering specifications of each individual customer, and in many cases we do not have orders for it. We have a piece of paper that says, "Our commitments for six months." If tomorrow the customer says, "We do not want to use that any more, that is your hard luck." If we have run a bank ahead, we throw it way; so we do not dare run any banks.

If you will study any subject of general business and many other things, you will find that a positive cycle governs all of it. That cycle, as Mr. Stiffler said, was toward too-high inventories 10 years ago to keep production up. Then the thought was that this was too costly; therefore, the striving has been, for 10 years, toward no inventories. At the peak and at the bottom of that cycle neither one of them is right. An in-between point represents an over-all best economy, which is exactly the same as our general business situation today. The peak of 1929 was wrong; the depression of 1931 is wrong. A place in between is right. Not only from the parts makers' viewpoint but also from other viewpoints we have a fetish of low inventory, which in principle is right, but have we not gone a little too far in some instances? The material men might give that a little thought.

CHAIRMAN RUMELY:—Inventory control involves other considerations besides investment. As was mentioned, it enables engineering changes to be made quickly, either to correct a design or to take advantage of an improved design that has come on the market during the season. We had the adoption of free-wheeling and Startix in the middle of the season, both of which decidedly changed the requirements of the parts in the car where those particular items were used. Close inventory control was of advantage to eliminate the reworking or scrapping of parts involved.

The supplier's interests are also benefited when rejections occur. If permitted to run a considerable quantity of material ahead at both his and your plant and then the machining process develops that the part is defective and must be rejected, the supplier may lose a considerable amount of money by replacement or reworking. Close inventory control in that case is of advantage to him.

We have also the case at the end of a season or the end of a model, where the sales department has to do some estimating as to how the split will be on various optional items such as model types, right and left-hand drives, body colors, trim cloth, free-wheeling, fender and bumper combinations and the like. In all optional equipment the nearer we can permit the sales department to approach the shipping date the more accurate the forecast will be and the less chance to have a surplus stock at the end of the season.

One or Many Sources of Supply

Would some of the other suppliers or manufacturers care to comment on how many suppliers we should have for any one part and how we should decide that question?

MR. UPTON:—Dodge Bros. generally decides that by an investigation of the plant—what the facilities are, what the temperament of the management is and, when it gets the business, what the attitude is toward further plant expansion to take care of the business. If the

attitude is that he wants the business and will take care of it, giving us deliveries as required, one supplier is generally sufficient.

MR. STIFFLER:—One good one is better than a half dozen poor ones. We largely go to one supplier, although we do have two for some temperamental pieces.

CHAIRMAN RUMELY:—You do not split one part among two or more suppliers?

MR. STIFFLER:—We do very little of that. Before we had a foundry of our own, we did business with one foundry for years and years. You cannot turn that kind of a supplier down. If he stays with you year after year, you stay with him.

CHAIRMAN RUMELY:—Formerly the tendency of the purchasing departments was to have duplicate suppliers on any one part. Of course, this results in complications when we come to material control, as the detail in the office is increased proportionately. If we split the business in a season such as we are just finishing, that reduces the size of the orders to each supplier and we cannot give him what he considers an economical lot-run. That is one of the big objections to this splitting practice. The suppliers rightfully have a complaint to make about small releases, but primarily that is due to the splitting of orders among a number of suppliers and to a very small total volume on top of that.

I do not want the suppliers to feel that the burden of this present period is being placed entirely upon them. What is expected of the material division in meeting schedules is impressive. No company today is turning down an order for an automobile, and, if it is humanly possible to get it out, it is being done. Let me cite a few figures to give some conception of what the material divisions, in general, are up against. Sales orders are received calling for almost immediate shipment because many dealer stocks are depleted, and, when an order is received, it must be filled with the minimum of waiting time. If we cannot make delivery, the dealer tells us that the purchaser will go to some other car manufacturer.

Effect of Fluctuations in Orders

Typical fluctuations in 1931 general orders are shown in the following tabulation which originally was intended to give the material division a three weeks' firm schedule but which 1931 conditions severely modified.

	Date of General Order				
For Week of	Oct. 5	Oct. 12	Oct. 19	Oct. 26	Nov. 2
Oct. 5	600				
12	450	590			
19	370	440	555		
26		350	420	530	
Nov. 2			330	400	500

We will use these figures just to demonstrate this point. On Oct. 5 the sales department has actual orders for 600 cars for that week and at that time it will probably have 450 for the week of the 12th and 370 for the week of the 19th. This represents advance orders that have been received. Theoretically these should be all orders accepted for these three weeks, so we have two weeks' time to give the material division to provide stock, which is short enough. This year conditions have changed to a point where we are accepting increased orders for delivery the following week and some for the same week and trying to fill them. This practice will result on Oct. 12 in our having probably 590 orders for that week, which is an increase of 30 per cent. Under such conditions the plants are working only a few days per week, for example, Wednesday and Thursday. That will give the material division about two days to get the material in case it has not guessed the schedule increase with sufficient accuracy. The Oct. 5 estimate of 370 for the week of Oct. 19 probably will grow to 555 by Oct. 19. This picture represents the handicap under which the various automobile companies and their material divisions have been working this year.

We can turn down the orders, but no one is that thoughtless today. The only other answer is to estimate the schedule in advance, and, where short to meet requirements, we have to call the supplier on the long-distance telephone and ask if he can run that night to get the material out. The problem has been very complicated for all concerned this year and, in justice to the suppliers, I must say that they have been asked to do and have accomplished many unusual things.

MR. JUHL:—In the General Motors Corp. what constitutes the authority of the vendor to fabricate, the purchase order or the release from the follow-up department?

MR. STIFFLER:—The order always; that is a positive commitment.

CHAIRMAN RUMELY:—Have all suppliers done everything possible to reduce their set-up expense? I know of a forgings supplier who has done a very wonderful thing in that respect. Formerly his die set-up, which is an expensive part of his program, required something like 24 hr. to make. By the use of a heavy-duty electric lift-truck he has been able to reduce this time so that he can have a large forging in the laboratory for checking within 6 hr. from the time he starts, which is a very good performance. The set-up time affects the lot size that a supplier, a car manufacturer or, as a matter of fact, any manufacturer can run economically.

Considerable study has been given this question by some car manufacturers and I am sure by many suppliers, especially during the 1931 season when the releases have been so small. We hear complaints, of course, from suppliers, and we also hear them right in our automobile factories when we give them a very small order. For example, in our automatic-machine division we might give a two weeks' release, but, if we are assembling cars only two days, or in some cases one day a week, the actual running time to get out parts for that program is half of the set-up time. Many cases like that occur, and I mention it to show that car manufacturers have been in the same predicament that suppliers have been in, and I think the latter will find that we appreciate the problems which they have faced.

We are hopeful that this condition will not last long and we soon will be able to increase the size of the releases. Of course, some immediate improvement in release size can be accomplished by having one supplier for any one part. I know of instances in which forgings have been split among five and even seven suppliers. In that case none gets an economical lot-run. Much work is being done on that question by the industry in general, and everything points to an improved condition for next year.

MR. STIFFLER:—I have been interested in the other side of the control of all working capital, even fixed assets for that matter, so as to spend the smallest possible amount of money and tie up the smallest possible amount, but I have always said that inventory control means control consistent with good business. Mr. Rumely is absolutely right about the point he made that this has a limit.

Lessons from Diesel-Engine Service

OBSERVATIONS from the field were reported by F. P. Grutzner, in charge of Diesel engineering of Fairbanks, Morse & Co., in a paper read at a meeting of the Chicago Section. The paper also included descriptions of representative Fairbanks two-cycle Diesel engines, the smallest being a two-cylinder 6 x 6½-in. unit having crankcase scavenging and developing 25 hp. and the largest a seven-cylinder 16 x 20-in. unit having a double-acting scavenging pump and rated at 980 b.hp. Service observations reported by Mr. Grutzner were as follows:

Importance of details has long been recognized in the design and installation of Diesel engines. Engines made from the best materials and with the greatest care are sometimes installed under such adverse conditions that it would have been better policy for us to have refused the orders. Hardness of the cooling water probably has been the largest single cause of difficulties in the field. Professor Junkers demonstrated in 1912 that the heat passing through the cylinder-wall of the Diesel engine may be several times greater than that passing through the wall of a steam boiler, and the conditions are very favorable for the formation of scale. As a result of much painful experience we have arrived at the following standard recommendations:

(1) Plenty of cooling water must be circulated through the jackets, and dead corners must be avoided to prevent the formation of steam. The temperature rise of the cooling water should be as small as possible, preferably 20 deg. and never more than 40 deg. fahr. Raw water at 100 deg. should be circulated at the rate of 20 to 25 gal. per b.hp-hr. Under no conditions should the circulation be less than 10 gal. per b.hp-hr.

(2) Conditions should be such that the water-outlet temperature is low. We limit the temperature to 120 deg. fahr. for raw water and 140 deg. for soft water.

(3) An indirect-cooling system should be used, wherever possible, in which soft water is circulated through the engine jacket and cooled in a heat exchanger by raw water. Very little make-up water is needed, and the formation of scale is reduced to the minimum. If an indirect system cannot be installed, the next best system is to use water once and let it run to waste as is done in most marine installations.

Fuel and Lubricating Oils

Qualities required to make an oil suitable for Diesel fuel have often been discussed, and many builders of Diesel engines have given recommendations as to the limits acceptable for chemical and physical analyses. We believe that this solution is not reliable and insist that a sample of the fuel in question be sent to the factory for an engine test. If the fuel consumption stays within the limits which we guarantee and the engine is clean after the run, the fuel is placed on the approved list. This is assuming that fundamental requirements, such as freedom from mechanical impurities and water and ability to flow through pipes and pumps, are satisfied. If the oil is too thick, it must be heated to lower its viscosity. Large slow-speed engines generally can burn heavier fuel than can small high-speed engines.

Various characteristics of the hundreds of fuel oils tested by us have been plotted on graphs for comparative study. By this means we have found that every fuel on our approved list has less than 3 per cent of carbon by the Conradson test and at least 50 per cent of its volume will distill off at 700 deg. fahr. We offer these characteristics, which are little mentioned in literature, for further study.

Lubricationg oils we test in a similar way; each sample is used in actual engine tests before it is released for use by the customer. Reliable information on the consumption of lubricating oil is difficult to obtain in short tests, and new engines run on the test floor usually are overlubricated. We are fortunate, however, in obtaining figures from installations where records have been kept for long periods. They show that the oil consumption of our large engines is as little as 1 gal. of new lubricating oil for 5000 hp-hr. rated. In calculating the efficiency of prospective Diesel installations we generally use the figure of 2500 hp-hr. per gal.

Clean Air Is Essential

Cleanliness of the air that is drawn in by the scavenging pump is as essential as is cleanliness of the fuel oil. We always recommend the installation of air-filters, and the majority of our large engines are equipped with them. They consist of cells providing irregular air paths that are covered with some sticky substance to which the dirt adheres.

Much harm has been done by overloading Diesel engines. Overheated cylinders, cylinder-heads and pistons, poor cylinder lubrication and increased wear or worse are the results. We check the anticipated load carefully to guard against this, and prescribe the propeller dimensions for marine installations. As these precautions are not a complete safeguard, we endeavor to give every type of engine a liberal overload capacity. Our normal overload test consists of a 2-hr. run with a 120-per-cent load, and we have recently tested one of our large engines under 162 per cent of its rated load for a short time without injury.

The waste heat contained in the cooling water and exhaust have been the subject of much study. So far we have been unable to obtain commercial apparatus for utilizing the exhaust heat without difficulties in cleaning or without back pressure on the exhaust system. The cost and added complication also prevent the general adoption of such schemes; and increasing efficiency of the engines results in lower temperature of the exhaust, which is generally lower in a two-cycle than in a four-cycle engine. Some of our customers have installed pipe coils in the exhaust system, and we have records of one complete test in which 8.2 per cent of the total heat supplied to the engine was reclaimed from the exhaust for use in heating air which was needed for some manufacturing purpose.

Some customers inquire regarding the use of the heat of the cooling water for heating or manufacturing purposes. Water at 120 deg. fahr., as it comes from the water-jacket, is usually not hot enough for such purposes.

The Interpolation Method in Routine Detonation Testing[1]

By Donald B. Brooks[2]

THE AUTHOR discusses the permissible interpolation interval for use in routine detonation testing as affected by octane number, engine, and adjustment of the bouncing-pin apparatus. Test results presented show that, with suitable adjustment, the use of a 10-unit interval does not materially reduce precision although it greatly reduces the time and the quantities of materials needed for the test. To determine an economical and practical method of suitably adjusting the bouncing-pin regularly and rapidly for the use of large interpolation intervals will require further research.

THE QUESTION of the suitable octane-number interval between the reference fuels used to "bracket" a test fuel in detonation rating became moot with the drafting by the Detonation Subcommittee of a proposed Recommended Practice. After much discussion, the Committee voted to adopt a standard interval of 2 octane units until research then in progress established the feasibility of using larger intervals.

Briefly, the advantages of the 2-unit interval are that:

(1) A considerable misadjustment of the bouncing-pin does not seriously impair the precision of the results.

(2) With the present accuracy of rating of about one unit, it practically eliminates interpolation.

(3) The intensity of detonation does not vary greatly with a 2-unit change in octane number, hence it is stated that the time-lag on switching from one fuel to another should be small.

It is also said that the use of a 2-unit interval gives greater assurance to the operator.

On the other hand, the use of a larger interval, in particular a 10-unit interval, results in the following advantages:

(1) It more than doubles the speed of testing.

(2) With proper adjustment of the bouncing-pin, the precision is equal to that obtained with a smaller interval.

(3) It facilitates interpolation and tends to discourage the stating of results to an unwarranted number of decimal places.

(4) It has not been found to result in an undue time-lag.

(5) No consistent or large differences have been found between results obtained with 2-unit and 10-unit intervals.

(6) A much smaller number of reference blends is required and the possibility of mistake in the value of a blend is eliminated.

Furthermore, it is believed that confidence in a type of measurement arises from the certainty, based on experience, that repeat measurements will check, rather than from the length of the "yardstick" used.

The four-bowl type of carbureter[3] proposed by the writer about two years ago as a means for expediting routine testing reaches full utility only when used with at least a 10-unit interval. With this carbureter and three suitable blends of the reference fuels, spaced at 10-unit intervals, it is possible to rate practically all commercial or all premium fuels[4] without changing the reference-fuel blends, thus eliminating the necessity of redetermining the carbureter setting for maximum knock for the reference fuels each time a fuel is rated and thereby further expediting testing.

For the foregoing reasons it was felt that a study should be made to determine whether the detonation-measuring apparatus was, or could be, adjusted so as to permit the use of an interpolation interval of 10 octane units without seriously impairing precision. Such adjustment would be obtained when equal increments in the octane number of the test fuel result in equal decrements in the rate of gas evolution under otherwise fixed conditions. The question whether the apparatus can be so adjusted can be settled, therefore, by measuring successively the rate of gas evolution for a series of fuels differing successively by an equal or a known number of octane units. Determinations were made in this manner in the test work described hereinafter.

TABLE 1—FUELS PAIRED FOR TEST RUNS

Pairs of Fuels	Range—60 to 70 Octane Number Octane Numbers
A, F	60, 66
B, G	61, 67
C, H	62, 68
D, I	63, 69
E, J	64, 70

Test Apparatus and Procedure

The test apparatus consisted of a General Motors Corp. fuel-research engine, an Ethyl Gasoline Corp. Series-30 engine, and two Cooperative Fuel-Research engines of the latest model.

General test conditions and the method of operation followed closely those at present used by the Detonation Subcommittee. By means of the bouncing-pin apparatus, from five to ten gas-evolution measurements were made on each fuel of a series of fuels of known octane numbers.

Since this work was done before a four-bowl carbureter was available, readings in alternation could be made on only two fuels at one time. It was then necessary to replace these fuels with the next pair, and so on. The effects of possible variations in readings due to changes in engine condition during the interval required to change fuels were obviated by use of correlation formulas developed[5] for this purpose. To permit the use of these formulas, the tests were run on the fuels paired as illustrated in Table 1. Runs were made

[1] Publication approved by Director of the Bureau of Standards, City of Washington.

[2] S.M.S.A.E.—Automotive engineer, Bureau of Standards, City of Washington.

[3] See S.A.E. JOURNAL, November, 1931, p. 411.

[4] See Bureau of Mines Report of Investigations 3152, 23rd Semi-Annual Motor Gasoline Survey, Part 3.

[5] See Minutes of Detonation Subcommittee Meeting, April 14, 1931.

TABLE 2—RESULTS OF TESTS ON GENERAL MOTORS ENGINE

Run No.	No. of Tests per Fuel	Range Covered, Octane Number	Sensitivity, Ml. Gas per Min. per Octane Unit × 100	Corrected to 10 Observations per Fuel: Precision of Matching, Octane Units	Mean Precision for 2-Unit Interval, Octane Units	Mean Precision for 10-Unit Interval, Octane Units
201	5	50-60	2.5	0.18	0.18	0.40
202	5	60-70	2.1	0.13	0.13	0.13
203	3	70-80	5.3	0.03	0.03	0.31[a]

[a] Altering adjustment of bouncing-pin greatly decreased this figure.

on each engine over the above range and also over the ranges 50 to 60 and 70 to 80 octane number.

From the data so obtained, the mean precision, expressed as the probable error of octane-number rating, was computed for a 2-unit and a 10-unit interval and also for exact matching. The results are given in Tables 2, 3 and 4.

What the Test Results Show

The results of tests on the General Motors engine, presented in Table 2, show that the precision of matching is higher at the higher ranges of octane number. Further, they show that, with unaltered bouncing-pin adjustment, the precision of rating with a 10-unit interval may be very materially less than that with a 2-unit interval. In the tests reported, this occurred in the 70-to-80 octane-number range. However, other tests, not sufficient in number to warrant inclusion in the table, indicate that this loss of precision with use of the larger interval may be reduced or eliminated by suitable readjustment of the bouncing-pin apparatus.

The results obtained on the Series-30 engine, and shown in Table 3, indicate the difficulty experienced in obtaining a bouncing-pin adjustment such that the use of a larger interval would not be accompanied by a material loss of precision. Such adjustment was obtained, however, for each octane-number range studied (Runs 3, 1-*B*, and 2).

These results are generally illustrative of the increase in sensitivity (column 4) that occurs at higher octane numbers. Sensitivity is defined as the response of the bouncing-pin apparatus to a unit change in the detonation of the fuel. It is expressed as change in the rate of gas evolution, measured in hundredths of a milliliter per minute, per 1 octane-unit change in the fuel. Runs 2 and 5 are of interest in that they also show clearly the absence of any definite dependence of precision on sensitivity.

The results of Runs 101 to 103 on the C. F. R. engine, given in Table 4, are believed to be typical of what may be expected from careful adjustment of the apparatus with this engine. The increase in sensitivity and improvement in precision at the higher octane-number ranges agree with other results. Run 104 is a horrible example of what may occur when using a large interval without suitably adjusting the bouncing-pin apparatus.

[6] See S.A.E. JOURNAL, August, 1931, p. 165.
[7] See Minutes of Detonation Subcommittee Meeting, Sept. 3, 1931.

TABLE 3—RESULTS OF TESTS ON SERIES-30 ENGINE

Run No.	No. of Tests per Fuel	Range Covered, Octane Number	Sensitivity, Ml. Gas per Min. per Octane Unit × 100	Corrected to 10 Observations per Fuel: Precision of Matching, Octane Units	Mean Precision for 2-Unit Interval, Octane Units	Mean Precision for 10-Unit Interval, Octane Units
3	3	50-60	3.6	0.09	0.09	0.09
4	1	60-70	3.4	0.26	0.26	0.42
1-*A*	10	60-70	4.8	0.07	0.07	0.48
1-*B*[b]	10	60-70	4.6	0.07	0.07	0.07
6	6	60-70	2.0	0.36	0.24	1.32
2[c]	4	70-80	6.5	0.17	0.17	0.17
5	5	70-80	6.9	0.08	0.09	0.78

[b] Run 1-*B* is data of 1-*A* excluding first pair of runs.
[c] First 5 points only.

TABLE 4—RESULTS OF TESTS ON REVISED C.F.R. ENGINE

Run No.	No. of Tests per Fuel	Range Covered, Octane Number	Sensitivity, Ml. Gas per Min. per Octane Unit × 100	Corrected to 10 Observations per Fuel: Precision of Matching, Octane Units	Mean Precision for 2-Unit Interval, Octane Units	Mean Precision for 10-Unit Interval, Octane Units
101	10	50-60	4.0	0.09	0.09	0.25
102	10	60-70	8.8	0.04	0.04	0.16
103	10	70-80	10.0	0.03	0.03	0.03
104	5	50-60	2.7	0.12	0.13	1.88
105[d]	4	60-70	8.3	0.13	0.13	0.69
106[d]	5	60-70	5.1	0.06	0.06	0.06
100[e]	5	50-70	2.9	0.10	0.10	0.10

[d] Tests run under identical conditions except sensitivity.
[e] Old L-head C.F.R. engine using 8 fuels.

High Sensitivity Does Not Assure High Accuracy

Runs 105 and 106 were taken for the express purpose of showing that high sensitivity is *not* a guarantee that high precision will be obtained with a large interval. Run 105 was made with the bouncing-pin adjusted for high "pin factor"[6]; for Run 106, the adjustment was such as to incur a minimum loss of precision with the use of a large interval. Not only did the latter adjustment reduce by tenfold the error obtained when using the 10-unit interval; it even halved the error of exact matching. As is the case with many other instruments, an increase in sensitivity does not imply an increase in precision.

The present optimum performance probably is represented by Run 100, in which practically no increase in error would occur with an interval of even 20 units. This was the first test to be made in connection with the problem of interpolation interval, and, as frequently happens, it solved the question quite happily until check tests were undertaken. It is possibly significant that the sensitivity was relatively low during this test.

From the foregoing, it is evident that an interpolation interval of 10 units can be used without seriously diminishing precision only if the bouncing-pin is suitably adjusted. That such adjustment can be obtained consistently is indicated by the tests reported in Table 5. In this work, six fuels were rated using a 2-unit interval. The same fuels were then rated (*a*) by using an interval so small (less than 1 unit) as to approximate exact matching and (*b*) by using a 10-unit interval. Partly, at least, because only the matching and the 10-unit interval could be run simultaneously, the average difference of the results with the 2-unit interval and by matching is ±0.50 unit, while results obtained by use of the 10-unit interval differed by only ±0.07 unit from those by matching.

While this cannot be interpreted as meaning that the

TABLE 5—COMPARISON OF MATCHING, AND INTERPOLATION WITH 2 AND 10-UNIT INTERVALS

Fuel No.	Sensitivity Ml. Gas per Min. per Octane Unit × 100	Octane Number: By Matching	2-Unit Interval	10-Unit Interval
1	1.1	47.1	47.5	47.3
2	6.7	98.2	98.7	98.2
3	2.1	68.2	67.7	68.2
4	1.2	56.4	55.7	56.2
5	2.0	64.1	63.7	64.1
6	2.0	77.1	76.8	77.0

NOTE:—Matching and 10-unit interval were run simultaneously; 2-unit interval at a different time. This probably accounts for most of the dicerence between 2-unit interval and matching.

10-unit interval is much superior to the 2-unit interval as regards precision, the differences stated probably are quite representative of the relation of the *accuracy* (0.50) and the *precision* (0.07) of detonation rating.

This investigation has shown what *can* be done in regard to the use of larger interpolation intervals. However, unless suitable adjustment of the bouncing-pin can be obtained *regularly* and *rapidly*, the major advantage of the 10-unit interval—that of economy of time and material—will be lost. Further work will be required to determine whether this is possible.

Conclusions

(1) Since a *precision* of even 0.5 octane number is greater than is warranted by the *accuracy* of present test methods[7], the use of an interpolation interval of 10 octane numbers, or more, is practical if the bouncing-pin apparatus be suitably adjusted.

(2) The results herein presented show that the bouncing-pin can be adjusted so as to yield a mean *precision* of 0.1 octane number when using an interpolation interval of 10 octane numbers in the range from 50 to 80 octane numbers.

(3) To determine an economical and practical method for suitably adjusting the bouncing-pin apparatus for the use of large intervals will require further research.

It is desired to express appreciation of the excellent work of Messrs. Rodgers, Bishop, and Carter in performing the necessarily exacting tests, and of N. R. White in checking the theory and computations involved.

German Reports on Fan Problems

THE FOLLOWING letter has been received from Ludwig Richter, professor of engineering at the State Polytechnicum in Vienna, Austria, and a Foreign Member of the Society, together with copies of the first three of the articles mentioned.

Sept. 17, 1931.

SOCIETY OF AUTOMOTIVE ENGINEERS,

Gentlemen:

In the discussion of A. D. Gardner's paper, Reducing Fan Horsepower and Noise[1], some problems are brought up which I treated and partly solved some years before, as you see from the enclosed articles, Berechnung der Luftröhrenkühler[2] and Die Wasserrückkühlung in Kraftfahrzeugen[3]. I hope they will be interesting to some of your members.

The enclosed paper, Kühlungsfragen bei Fahr- und Flugzeugen[4], should demonstrate systematically how many things there are to explore in the cooling systems.

Since that time two very remarkable reports came out in the German literature: Untersuchung von Automobilkühlern[5], by K. Dehn, and Die Berechnung und Messung des Temperaturverlaufs in Wärmeübertragungsrippen[6], by C. Bogaerts and P. Meyer.

(Signed) Richter.

[1] See S.A.E. JOURNAL, August, 1931, p. 109, and S.A.E. JOURNAL, September, 1931, p. 228.

[2] See *Zeitschrift des Vereines deutscher Ingenieure*, March 13, 1926.

[3] See *Zeitschrift des Vereines deutscher Ingenieure*, No. 23, 1927, p. 827.

[4] See Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, Heft 300, VDI-Verlag, Berlin.

[5] See Forschungsheft 342 des Vereines deutscher Ingenieure, Berlin, 1931.

[6] See Forschung, Bd. 2, 1931, No. 7, p. 237.

Saving Weight and Cost in Airplanes

MANY OF THE AIRPLANES now built are not economically designed with respect to weight and cost. Compared with the methods of automobile production design, each airplane is a custom-built job. Until the designers get together and make an effort to standardize and simplify such parts as wing fittings, control surfaces, hinges, elevator and rudder horns, stabilizer-adjustment mechanisms, cockpit control systems, wing ribs and the like, airplanes will remain custom built and the price accordingly high. A great deal could be saved by the manufacturer if many small parts of one model were used on his other models. There is no apparent reason why all drag-wire fittings, for instance, could not be the same for all airplanes in the 1500 to 2500-lb. class. A comparison of the cost of stamping these fittings from one set of dies with the cost to an individual manufacturer of making them up by hand would be of interest.

The inefficiency of design of many airplanes from a weight consideration is made evident by the margins of safety of structural members. These margins range from a negative 3 or 4 per cent to a positive 1500 per cent, with the high positive margin not always due to structural reasons.

In many cases the design itself is responsible for unnecessary weight. This is caused by the arrangement of wires or struts with reference to the surrounding structure. An example of this is an airplane having too flat an angle of the wing-lift wires or struts with the wing spars, resulting in lift-wire and spar-end loads of a magnitude which would be found in a well-designed airplane of three or four times its weight.

In many cases, when contemplating a new or unconventional type of construction, the manufacturer might save considerable time and expense by discussing his assumption with the Department of Commerce and obtaining a ruling as to the method and amount of analysis that would be required as well as any necessary static tests.

Some time ago a certain manufacturer contemplated a new design and, before beginning the preparation of the technical data, prepared a 30-page report outlining proposed methods of analysis on points not entirely covered in Bulletin 7A. A great deal of time in making corrections and possible changes in the structure was thus saved. This procedure is highly recommended for all manufacturers contemplating a design which is not thoroughly covered in Bulletin 7A.—From a Southern California Section paper by Stanley S. La Sha, chief engineer, Aeronautics Branch, Department of Commerce.

Transportation Engineering

Chassis Lubrication

A. J. Scaife's[1] Comprehensive Transportation-Meeting Paper Summarized and Ably Discussed[2]

A CROSS-SECTION of present opinion on chassis lubrication was sought by Mr. Scaife who based his Transportation Meeting paper on an analysis of replies to a questionnaire received from representatives of six motor-vehicle operators, five motor-vehicle manufacturers, four lubricant manufacturers, two trade papers and one consulting engineer.

One operator recommended considering the vacuum system of oiling chassis steering mechanism and clutch bearings, and the installation of a reserve engine-oil reservoir for long trips to assure uniformity of price and quality of the lubricant.

An operator of 230 motorcoaches developed specifications for engine oil having a range wide enough to include all types of motorcoaches in operation, as well as a tank for oil that can be readily drained into the engine crankcase to give continuous use of only one oil. He advocates using the same policy for purchasing chassis lubricants, using the lowest possible number of kinds to lubricate the vehicles.

In a fleet of about 100 vehicles, operating from 20 to 100 miles each per day, lubrication cost about $1,524 per year. Wick-feed oil-cups were installed and reclaimed crankcase oil was used. The total cost, including investment, was $791. The first year's saving was $753, with a decrease in parts replacement, but, should there have been an increase, the company would have had $753 to use. The saving the second year was $1,208. A recent purchase of newer and cheaper trucks did not include the installation of oil cups, but the comparative parts costs were lower. Engine lubricants originally were changed at 500 miles, then at 750, 1000, and 1500 to 2000 miles. Tests were made up to 5000 miles, and consideration is being given to a 10,000-mile basis.

An operator in the Middle West suggests that engineering design can eliminate the necessity for lubricating chassis parts, and that the frequency of lubricating engine and chassis parts can be controlled by lubricating systems that are in vogue or by engineering design. He believes that the ideal system is one that provides automatic chassis lubrication.

Periodical Oil Draining Advocated

A motorcoach operator in the East suggests that engine miles be used as a basis instead of road miles for oil changing and overhauling. As to never draining the crankcase, this operator quotes an authoritative opinion that within a year, more oil will be used in a vehicle where no draining had been made than in one where draining after 2000 miles was practised and the oil reclaimed. A comparable cost method of draining, refilling and reclaiming, compared with the cost of simply adding more oil without draining, is advocated, as well as using one lubricant for the entire chassis excepting the engine.

Another operator in the Middle West advocates draining every 1000 miles in summer, every 500 miles in winter, and, when it is very cold, as often as every 300 or 400 miles. In the larger operations, all the oil is reclaimed. Chassis are greased at least once a week and different lubricants are used for the different parts of the car. One grade is used for shackle bolts and steering-knuckle pivots; another grade for the water-pump, fan bearings, steering-gear, universal-joints, wheels, transmission and rear axle. This operator uses six grades of engine oil and nine grades of grease.

Oil-Company Reactions

A representative of a large western oil company advocates placing emphasis on tests evaluated in terms of service performance, believing that a weakness in this respect exists in the recent classification of transmission and rear-axle lubricants. The undefined statement "must not channel in service," he asserts, which heads the list of specified temperatures, leaves one in doubt as to just how the determination should be made. If all that is desired in a standardization system is a list of names or designated numbers together with the limited qualification that the products must give satisfactory results under certain service conditions, there should be no great difficulty in arriving at such a tabulation. The standardized classification should be more definite than in this particular case.

This same representative states that a system of indicating the value of the so-called extreme-pressure lubricants is needed to avoid confusion. Special lubricants for spring bolts and shackles, steering-knuckle pins, steering-gears, water-pumps, universal-joints, chassis springs and wheel bearings, may be considered essential by some, but specialized lubrication can be, and frequently is, carried too far. To have special products for all of these items is unnecessary. Merely to assign names or numbers to broad classifications of lubricants with qualifying statements such as "must not separate in service," "must resist the action of boiling water," "must not cause lapping or excessive wear of antifriction bearings," "must resist the centrifugal effects of universal-joints," "must be capable of maintaining a lubricating film under conditions of extreme pressure," and then leave the question of evaluating these requirements to the several hundred compounders in the Country cannot lead to the most useful form of standardization.

Wants Problem of High-Pressure Lubricants Solved

Another representative of a large eastern oil company advocates the use of top oilers or upper-cylinder and valve lubricants; first, a very light spindle or neutral oil which is added to the gasoline, and, second, chlorinated compounds which consist of light spindle or neutral oils to which carbon tetrachloride or some other such product has been added. This is recommended especially for new or newly overhauled engines. He further suggests that the merits of so-called high-pressure lubricants such as sulphurized gear lubricants, straight lead-soap greases and lead-soap sulphurized greases, be discussed; and that the problem of lubricating worm gears be solved by using lubricants resistant to oxidation at high operating temperatures.

An individual in the oil business considers the *maintenance dollar* most important to the fleet operator and says that correct lubrication plays an important part. Further, he states that the correct lubricant to meet all conditions should be a heavy oil stock that has great adhesiveness to metal, will not squeeze out, will hold an oil film and, when in contact with water, will not wash off.

Another representative of a large eastern oil company refers to the 1931 instruction books for the various makes of passenger-cars and says that they call for more than 14 different kinds (not brands) of lubricants needed; in addition, 3 or 4 grades (not brands) of engine oil, and 2 grades of gasoline, this being a total of 20 distinct products theoretically required to lubricate cars and make them run properly, or about twice as many as any one service station is willing to carry.

This same representative suggests that it is to the advantage of all passenger-car and motor-truck manufacturers interested in promoting special chassis lubrication to make a careful study of the mechanical requirements of present chassis design with a view toward reducing the number of lubricants recommended, and that, in designing new chassis, first consideration be given to the matter of whether the design can be lubricated by the types of lubricants now on the market.

Engine Builders' Opinions

In the opinion of a representative of a large-scale engine manufacturer, lubrication development has become complicated because of the combination

[1] M.S.A.E. — Consulting field engineer, White Motor Co., Cleveland.

[2] The discussion is to be printed in the next issue of the S.A.E. JOURNAL.

of greater extremes of operating temperature, greater speeds and greater pressures, not to mention the considerably more critical attitude of users with respect to smoothness of operation, durability of parts and ease of maintenance. He notes that, where any real originality was shown in mechanical development, the types of lubricants originally employed proved inadequate. The producers of lubricants therefore were called upon to develop improved lubricants and these, in turn, both required and made possible newer and better methods of utilization. He believes that the natural trend of this type of development has been the present climactic condition with respect to automotive lubrication in which from seven to a dozen separate and distinct types of lubricants are required to care for the needs of a chassis and its engine, and that almost every important component part of the vehicle has had to be specially developed to permit these lubricants to do their work. He concludes that the time will come when it will be necessary for vehicle designers to settle upon perhaps not more than three different lubricants to be used for the standard vehicle, and then to select the highest type of available lubricants and deliberately design all of the parts to function efficiently with such lubrication.

The metallurgist for a large-scale motor-vehicle manufacturer states that it is not a question of not knowing what the users want but of having the lubricant manufacturer interpret the operators' descriptions of what they want; that is, a better understanding of the language used is needed.

An engineer of a large-scale engine-manufacturing company states that the main items with which the engine builder is concerned are crankcase oils of the right viscosity and flash point and high melting point, and non-soluble-grease specifications for water-pump grease, because considerable trouble is caused by using ordinary grease in the water-pump and putting excessive amounts into the pump cooling-system due to the use of pressure guns.

The chief engineer of a large motor-truck manufacturing corporation asks for the conclusions of operators concerning the use of free sulphur in lubricating oil, an analysis of the demand by operators for automatic lubrication, and data on the effect of oil coolers on the life and efficiency of engine parts.

The president of an engine-building company believes that engine lubrication is tied up very closely with the number of revolutions per minute of the engine, and suggests a right type of oil, a good oil-cleaner that can be taken off and cleaned, the use of a very good air-cleaner and of an oil reservoir of the wick type.

[3] See *Automotive Industries*, June 20, 1931, p. 943.

[4] See *National Petroleum News*, May 27, 1931, p. 85.

TABLE 1—PRINCIPAL CHASSIS UNITS TO BE LUBRICATED

Unit	Bearings	Lubricant Used
Fan	Plain or Antifriction	Oil or Grease
Water-Pump	Usually Plain	Grease
Distributor	Plain	Grease
Clutch Bearing	Plain or Antifriction	Oil or Grease
Transmission	Plain or Antifriction	Oil or Grease
Axle	Plain or Antifriction	Oil
Universal-Joints	Usually Plain	Oil or Grease
Steering-Gear	Plain or Antifriction	Oil or Grease
Steering-Knuckles	Plain or Antifriction	Oil or Grease
Drag Links	Plain	Grease
Front Wheels	Antifriction	Grease
Rear Wheels	Antifriction	Grease
Spring Pins	Plain	Oil or Grease
Miscellaneous Parts	.....	Oil or Grease

Editorial Opinions Quoted

The technical editor of a trade journal refers to an article and two published letters.[3]

An article entitled, Specialized Lubrication Requires Variety of Oils and Greases,[4] elaborates the different types of oil to be used in the different cars.

A consulting automotive engineer on the Pacific Coast writes that the present tendency is toward a single lubricating system whereby all of the chassis joints are lubricated from one station.

Replies to Questionnaire Analyzed

Mr. Scaife states that only the high points of the replies are included and that they show clearly that the present method of chassis lubrication is not satisfactory to the users of motor equipment; further, that individuals are trying to solve the problem in their own way by writing their own specifications, and, while all do not agree as to the method, all do agree as to the need. He lists in Table 1 the principal chassis units to be lubricated, two grades of gasoline being used generally for the engine and several kinds of oil.

It will be noted in Table 1 that two kinds of bearings are used on all these units, Mr. Scaife points out and asks: "Why should a plain-bearing fan, a plain-bearing water-pump and plain-bearing universal-joint use a half-dozen different grades and kinds of grease?" In the first case it would be only a matter of clearance as to whether grease or oil should be used; in the second, if the bearing is located so that the grease becomes hot and runs out, this should be a design problem and not a grease problem.

Universal-joints are often packed with a heavy fiber grease to prevent the grease from throwing out because of the design. In fact, Mr. Scaife states, we have used oily waste and packed the joints in a manner similar to that of a railroad-car journal to prevent throwing out due to centrifugal force, instead of taking advantage of the centrifugal force to lubricate the bearings in the universal-joint inside of a sealed container. Some of the universal-joint manufacturers have only recently adopted this new method.

Using a Palliative Instead of Cure

We have been trying to correct faulty design with different kinds of oils and greases, Mr. Scaife continues; that is, we have been working on the effect instead of the cause. To illustrate, much work has been done trying to remove the vapor-locking tendency of gasoline, instead of analyzing the cause for vapor lock, which was due primarily to the fuel devices being located under the hood where the temperatures are above the initial point of the fuel. According to his understanding, many of the vehicle manufacturers are now locating these devices on the chassis to eliminate vapor lock instead of trying to prevent it by using fuels that do not have vapor-locking tendencies.

Mr. Scaife recommends that this problem be studied by the Society from a design standpoint, giving consideration to pressure lubrication, individual-magazine lubrication, and central-station or so-called one-shot lubrication, and at the same time also to the required clearance for the working parts under each system.

If this is done, Mr. Scaife believes it will eliminate the necessity for many so-called special greases and make possible the lubrication of the chassis with not more than three kinds of oils or greases. This may seem like an impossible task at present, but to him it is very similar to a previous situation with reference to the different kinds and grades of gasoline that were on the market. While there may be several brands of gasoline, it is possible to confine fuel requirements to two grades that will work satisfactorily in practically all of the modern engines with fairly uniform results. If it is possible to purchase gasoline, using a definite specification without resorting to a flock of qualifying statements, he inquires, why not apply the same engineering thought to the selection of a lubricant for the chassis, including the engine, transmission and axles, and develop a standard that would eliminate the chaotic condition that exists today?

Production Engineering

Automobile-Body Sheets

Properties of Steel for Body Building

By R. O. Griffis[1]

SHEETS, to be most suitable for producing automobile bodies, must be such that they can be formed without breaking, necking down, wrinkling or buckling and that the surface of the finished part shall be free from defects which would cause excessive finishing costs. The problems of the body builder today, in making difficult stampings and producing good-looking cars with only two or three thin coats of lacquer, are many and varied.

Automobile-body sheets are made today by three chief methods: (*a*) the hand-operated hot mill, which is a modified form of the original sheet-bar practice; (*b*) the continuous hot-mill practice; and (*c*) the continuous cold-mill process, working on either coils or single sheets. Typical sequences for producing high-finish sheets by these three methods are shown in Table 1. A wide variation in the physical properties and appearance of sheets can be produced by varying these steps.

Grain Structure Affects Suitability

Grain structure is by far the most important feature of the modern deep-drawing sheet. Fig. 1 shows typical structures. The coarse-grained structure shown at the left would be unsuitable for a highly finished product which requires any forming at all, because the large grains would cause a rough condition over the surface. The second and third structures represent coarse-grained normalized sheets that are satisfactory for many purposes but will not stand the most severe drawing operations and will coarsen to some extent at sharp draws or beads. When the grain in a sheet is large enough so that it shows on beads, the part not only has to be ground, which adds to the finishing costs, but may split in service, as the coarser-grained material is more brittle after forming. I consider the structure designated as No. 4 to be the ideal structure for an extra-deep-drawing sheet. Sheets with grains as fine as shown at the right in Fig. 1 would be too stiff for many purposes; they would buckle in drawing or spring back out of shape after forming.

The effect of various rates of cooling from the normalizing temperature upon the grain size of an automobile steel sheet is shown in Fig. 2. The sheet shown in the view at the left was cooled at the slowest rate and the one at the right at the fastest rate. It will be seen that the grain size becomes smaller as the cooling rate becomes faster.

In general, the drawing qualities of sheets improve as the grain size becomes finer. However, the sheets become harder as the grain becomes smaller and require a greater hold-down pressure to prevent wrinkling or buckling. For this reason, coarse-grain and fine-grain sheets cannot be used interchangeably without some die adjustment, although both types are entirely satisfactory for many jobs. The finest-grained material is produced by the continuous operation, in which sheets or long strips are fastened together in an endless band and normalized at a relatively high rate of speed; the cooling rate cannot be made fast enough in the ordinary normalizing furnace, which anneals in packs of two or more on carrier sheets.

TABLE 1—THREE SEQUENCES OF OPERATIONS IN PRODUCING AUTOMOBILE SHEETS

Modified Sheet-Bar Practice	Continuous Hot-Mill Practice	Continuous Cold-Mill Practice
Hot-roll to sheet bar	Hot-roll to thin bar	Hot-roll to thin bar
Pickle bar	Pickle thin bar	Pickle thin bar
Hot-roll to breakdown		
Pickle breakdown		
Hot-roll to gage	Hot-roll to gage	Cold-roll to gage
Normalize or first box-anneal	Normalize or first box-anneal	Normalize or first box-anneal
Pickle	Pickle	Pickle
Cold-roll for surface	Cold-roll for surface	
Second box-anneal, bright	Second anneal, bright	Second anneal, bright
Cold-roll for temper	Cold-roll for temper	Cold-roll for temper

The finer-grained normalized sheet is much the more satisfactory for many parts, such as radiator casings. However, the large-grained soft sheet is more suitable than the finer-grained sheets for parts such as hood tops, for which a sheet must hold its shape without springing back after a simple forming operation.

Sheet Testing

Everyone connected with the production or use of deep-drawing sheets agrees that some test which would predetermine the drawing properties of a sheet would be very valuable if it could be devised. Such a test would be valuable to the consumer, as he could determine with assurance whether or not sheets in his warehouse were suitable for the jobs for which they were bought; and it would be of more value to the sheet maker, because in the end he is responsible for the sheets' doing the jobs satisfactorily. In cases of doubt, a really dependable test would help in fixing the responsibility for trouble; that is, it would determine whether the sheets were improperly made or were not being given the proper chance in the press-room.

A committee made up of representatives of the American Society of Mechanical Engineers, the Society of Automotive Engineers, the American Society for Testing Materials, the American Steel Manufacturers' Technical Committee, and the Pressed Metal Institute has been appointed to study the problem, and it is to be hoped that it will be able to devise a test that is much more helpful than any we have at present.

Every once in a while an engineer of some sheet user will set up Olsen, Erichsen, Rockwell, tensile, or chemical specifications or a combination of

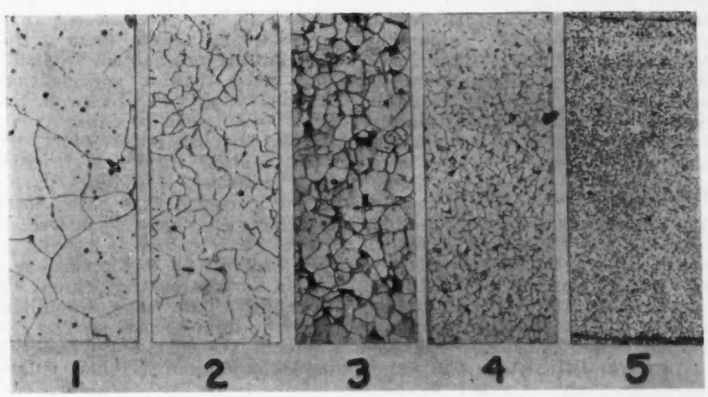

FIG. 1—MICROGRAPHS SHOWING GRAIN SIZE OF STEEL SHEETS
Magnification, as Reproduced, 61 Times Size

[1] Associate director of research laboratories, American Rolling Mill Co., Middletown, Ohio.

several of them. Such specifications usually are based on tests of a large number of sheets which some producer has made in such a way that they do the job satisfactorily. If the limits are set to include say 90 per cent of the sheets that had proved satisfactory, with the idea of rejecting in the future the 10 per cent which fall below the minimum thus indicated, they are almost sure to get the sheet maker into trouble. The same factors which caused 10 per cent of the material tested in setting up the specification to fall below a certain limit will keep on causing the same percentage to fall below in future orders.

Some of the factors which, at the present time, are beyond the absolute control of the manufacturer are: (*a*) ingot segregation, (*b*) slight chemical variations between different heats of steel, (*c*) unavoidable variations in normalizing temperatures or cooling rates, and (*d*) variations in items like gage and surface conditions. The chances are 10 to 1 that the material rejected for being below specifications on account of these natural variations would do the job as well as the 90 per cent passed. All of the material in the shipment would have been processed alike; which is the really important matter, regardless of the results of any physical tests. The consumer spends much time and cuts up many valuable sheets in testing, if this plan is rigidly carried out, and it becomes very expensive to him.

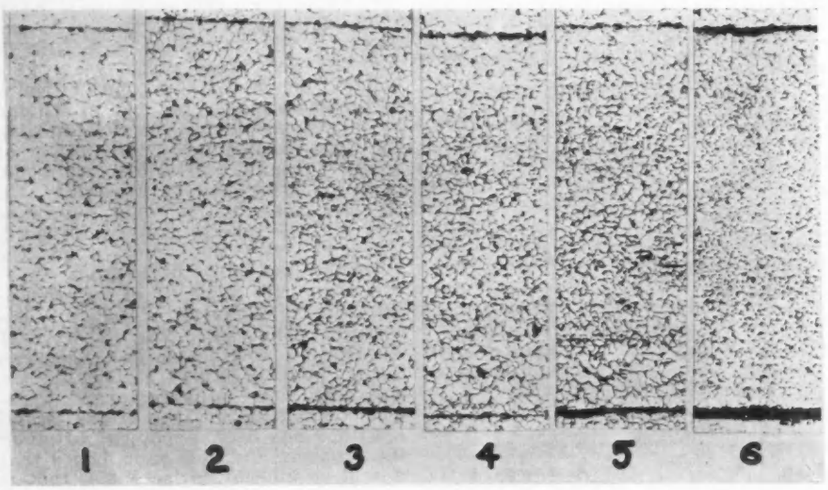

FIG. 2—EFFECT OF RATE OF COOLING ON GRAIN SIZE

Magnification, as Reproduced, 61 Times Size. The Slowest Rate Produces the Coarsest Grain (Left) and the Fastest Rate the Finest Grain (Right)

How Shops Can Cooperate

My experience has always been that the press shop which buys its sheets to do a certain job and works very closely with the producer has the least trouble. If the press shop notifies the maker that his last batch of sheets was a little too soft and stretcher-strained slightly, was a little too stiff and buckled, or was so stiff that the lot had to be rejected for breakage on the press, the sheet maker knows just what to do to make the next order more nearly what his customer wants.

To report that sheets are rejected on some physical test means nothing to the maker and does not help him to improve his service to the customer. For example, if a Rockwell hardness of B-55 or B-58 is reported when a maximum of B-53 was specified, he does not know but that the machine used in his own laboratory in testing the same sheet may have shown five points higher or lower than the customer found. What is more important, neither he nor the customer who rejected the lot knows from what part of the ingot the sheet tested came. As was pointed out at the recent meeting of the Steel Treaters in Boston, the natural segregation in a steel ingot of the grade used to make automobile sheets is enough to cause more than a 10-point variation in the Rockwell hardness of sheets from the same ingot. The fact that the breakage on even difficult jobs can usually be held below 3 per cent indicates that this difference in Rockwell hardness does not cause trouble.

Someone may yet succeed in making deep-drawing sheets from a grade of steel that is not subject to such variation; until then, a specification of a 10-point range in Rockwell hardness seems to be sure to cause trouble unless the purchaser uses some discretion about holding rigidly to his specification. However, if a sheet user knows from experience that sheets of a certain hardness range work well, and he prefers that temper to others, it is of considerable help to the sheet maker to be told to aim at that range. This is particularly true when the mill has not made the item before.

Within the last few years, the demands made upon the sheet maker have been unusual and, we believe, unreasonable in many cases. Sheets have been required for complicated draws, such as the one-piece fender, which combines the fender, fender skirt and hood ledge into one piece, with probably an additional draw for a battery box thrown in for good measure.

Demands Made on the Sheet Maker

Mills have been called upon to furnish light-gage sheets of very wide widths, which offer many sheet-mill difficulties. If the mill succeeds in rolling such sheets, they must be heat-treated in such a way that they too will work for the most difficult drawing operations. For instance, we supply a 19-gage sheet 74 in. wide by 79 in. long for a coupé quarter panel; which includes a window, a wheel house, a rear-deck side and part of the fuel-tank cover.

We recently had an inquiry for 20-gage, 74 x 78-in. and 66 x 140-in. sheets. They are just a little ahead of us yet. I have heard rumors that the makers of some of the smaller cars contemplate stamping out in one piece an entire half of the body, including the dash, and butt-welding it to the other half.

Whether or not the users' demands are reasonable, some real progress has been made in the quality of sheet steel. To my mind, the most important development has been the discovery of ways to produce a normalized sheet with a surface equivalent to that of a box-annealed sheet or of cold-rolled strip steel. Not all of the advances that have been made in the sheet-stamping art during the last five or six years can be credited to the sheet maker, because die design and shop practice have played just as important a part.

A press shop can do many things to help the metal to perform satisfactorily or to spoil it. For example, a promiscuous spreading of die lubricant on a large and difficult stamping will result in the buckling of the best sheet made. If the lubricant is improperly applied, the form will break, but if it is applied in the right quantity and in the right places—in other words, applied by a man who knows his business—the sheet will work perfectly.

I recently heard of a very interesting instance of a lot of sheets that had been rejected for breakage. In a retrial, the stop pin was broken off and the blank was pushed back about an inch further in the die. The sheet could then be drawn without trouble, and the rest of the rejected lot was worked in the same way and proved to be satisfactory. From this it can readily be seen that the line between satisfactory and unsatisfactory performance is not well defined and can be changed considerably through the intelligence and skill of the press operators.

I cannot emphasize too strongly the necessity for facing our problems jointly and recognizing the fact that only by the closest cooperation between sheet producer and press shop can the difficult tasks before us be successfully performed.

News of the Sections

Three Aviation Talks at Pittsburgh Cooperative Meeting

NINETY-TWO dinner guests and a total attendance of more than 100 enjoyed the aeronautical meeting of the Pittsburgh Section held in the rooms of the Chamber of Commerce on Dec. 1, with the cooperation of the Aeronautical Chamber of Commerce of America, the Aeronautics Committee of the Pittsburgh Chamber of Commerce and the Aero Club of Pittsburgh.

B. H. Eaton, Chairman of the Pittsburgh Section, introduced the toastmaster, Maurice R. Scharff, president of the Main Aeronautics Co., who told how, throughout American history, Pittsburgh had held its place as gateway to the West. Now two great transcontinental airways converge in the city, with others from the North and South. And Pittsburgh has built one of the greatest air terminals in the world, embracing 625 acres, of which 130 acres is paved, with four complete runways available ranging in length from 1750 to 3500 ft.

William B. Stout, speaking on the subject of The Airplane of Mr. John W. Public, said that women will soon be as important a factor in the purchase of airplanes as they now are in the buying of automobiles, and that to secure their approval the airplane must be quiet, because, "if any noise is to be made, the woman wants to make it herself." Also the airplane will have to look right, as well as stay up in the air, before it will sell in large numbers.

"To be a commercial success," said Mr. Stout, "the airplane must be capable of supporting itself in the air financially as well as physically. Since it costs a certain overhead per hour to keep a plane in the air, the most effective way of increasing its profit-producing abilities is to increase its passenger-miles per hour by increasing the speed. With higher speeds, the passenger will be satisfied with less space for comforts, as he knows the trip will be short."

Military versus Commercial Planes

D. W. Tomlinson, vice-president and operations manager of T. A. T. and Western Airways, whose subject was Engineering and Its Relation to Aviation, said that aviation is essentially an engineering industry and many of the greatest improvements in airplanes are due to the metallurgists, who have given us metals possessing strength and stamina that were unknown a few years ago. Two-thirds of all the airplanes and engines built in this Country go to the Army and Navy, he continued, and the safety factors must be abnormally high. This entails additional weight in the members which carry these loads. On the other hand, the existence of the commercial airplane depends on its revenue load.

"The finest airplane today is no safer and no more dependable than the pilot who flies it," asserted Mr. Tomlinson. "We now have gravity fairly well beaten but bad weather still puts us down. Application of the radio telephone has proved the greatest single step in overcoming the weather."

G. O. Hoglund, aeronautic engineer of the Aluminum Co. of America, speaking on Aluminum Alloys Used in the U. S. S. Akron, outlined the characteristics of some of the strongest alloys and said that advances made in the construction of dirigibles can be applied to the construction of airplanes. He gave in detail the physical properties of various aluminum alloys and said that the alloy used in the Akron is known as 17SRT, which has an average tensile strength of 46,000 lb. per sq. in. and an elongation of 10 to 15 per cent in 2 in.

Motion pictures of the actual construction of the Akron illustrated Mr. Hoglund's discussion, and two talking motion pictures were shown, including Wings of Tomorrow, with slow motion pictures of the action of the Autogiro when flying under various conditions, and a new talking motion picture just released called The Voice of the Air, which showed the application of the radio telephone to airplane use.

A Novel Engine Described

AN OPPOSED, two-cylinder, air-cooled engine designed for wing mounting in an airplane was described and exhibited by the inventor and designer, Harry Hedges, at the November meeting of the Northwest Section, held on the 13th at the New Washington Hotel in Seattle. This engine fires on both sides of the pistons, making it in effect a four-cylinder engine. The connecting-rod is encased in a nickel-iron sleeve, and contracting piston-rings are used around the connecting-rod sleeve as an effective gas seal around the rod. A very desirable ratio of horsepower to weight is obtained by reason of the unusual firing arrangement. Lively discussion followed Mr. Hedges' explanation. Among those who took part in the discussion were Valentine Gephart, Sherman Bushnell, C. H. Bolin and James H. Frink.

Prof. E. O. Eastwood, director of aeronautic and mechanical engineering at the University of Washington, made an address on the subject of transportation. He reviewed the development of transportation since the use of the skid and the invention of the wheel in prehistoric times, but gave particular attention to the more recent developments in aircraft.

The Secretary of the Section was instructed to have prepared and to present to the family of Arthur D. Hoge a suitable expression of the sympathy of the Section for the death of Mr. Hoge, a member of the Section, in a recent airplane crash in Snoqualmie Pass when returning from a hunting trip.

Chicagoans Consider Highway Transport

ONE OF THE LARGEST meetings of the Chicago Section was held the evening of Dec. 1 at the Sherman Hotel, with a dinner attendance of 139 and a technical-session attendance of 163. The subject of the evening was automotive transportation.

A. J. Scaife, of the White Motor Co., the first speaker on the program, discussed the controversial subject of rail and highway transport competition. He reminded his hearers that the original mode of travel was over the roads and by stage coaches and that when the advent of the railroads put the stage coaches out of business, the railroads were not in the least disturbed about their effect on the operators and investors.

Until a few years ago the railroads were strong supporters of highway improvement, said Mr. Scaife. Then the electric railway came to bridge the gap between producer and consumer, especially in the handling of farm products, but did not complete the transportation transaction, and the horse and wagon continued as a transport means. Today the motor-truck does the same kind of work in a better way, but carries heavier loads greater distances at higher speed.

Motor-Vehicles Pay for Roads

Motor-vehicles created an insistent demand for better roads, and the Chief of the Bureau of Public Roads was cited by the speaker as authority for the statement that slightly more than 80 per cent of the cost of construction and maintenance of highways is paid by motor-vehicles through special taxes. And, although motor-trucks and motor-coaches constituted only 13 per cent of the vehicle registrations in 1930, they paid $270,000,000, or 27 per cent of all motor taxes.

Only 7 per cent of all trucks are common carriers, according to a survey made by the Bureau, and of these only about one-third are operated by truck lines over regular routes. Regarding regulation and taxation of motor-vehicles and railroads on a similar basis, Mr. Scaife said that he could see no reason why those who paid for construction and maintenance of the highways should have their transportation costs increased because the railroads must pay taxes on their private rights of way.

Practical Trailer Transportation was the title of an address given by R. B. Jones, chief engineer of the Trailer Co. of America.

Discussion on the evening's papers was lively and was participated in by Warren Russell, of the Chrysler Motor Corp.; A. W. Scarratt, chief engineer of the International Harvester Co.; A. H. Gossard, vice-president of transportation of the Middle West Utilities Co.; G. W. Lupton, of the Atchi-

son, Topeka & Santa Fe Railroad; and Lee Landon, of the F. Landon Cartage Co.

Joint Aeronautic Meeting at Baltimore

LIEUT. Carl B. Harper and Temple N. Joyce were the speakers at a joint meeting of the Baltimore Section and the Aeronautical Chamber of Commerce of America on Dec. 10. The meeting was held in the Emerson Hotel, where a dinner was served to 84, to the accompaniment of a musical entertainment, and 95 members and guests of the two organizations were present to hear the speakers.

Lieutenant Harper, of the Bureau of Aeronautics of the Navy Department, spoke on the subject, Reducing Accidents. Mr. Joyce, vice-president and general manager of the Berliner-Joyce Aircraft Corp., gave a non-technical talk on Engineering and Its Relation to Aviation. Motion pictures of airplanes in action and showing thrilling views of men jumping to safety with parachutes from a transport and from a plane in a spin were a pleasing feature of the evening.

Canadians Give Loving Cups

R. H. ("BOB") COMBS and A. S. ("Alex") McArthur were recipients of encomiums and loving cups from their fellow-members at the November meeting of the Canadian Section, held at the Royal York Hotel in Toronto on the evening of the 18th. Sixty members and guests had assembled for the jolly occasion. Mr. Combs' cup was inscribed, To the Father of the Section; and Mr. McArthur's, To the Godfather of the Section.

In his presentation remarks, Chairman George W. Garner said that Mr. Combs joined the Society in April, 1912, was Chairman of the Indiana Section for a year and later its Secretary-Treasurer, had served as Chairman of the Membership Committee of the Society, as a member of the Standards Committee, as a Councilor and as a Vice-President. Mr. McArthur, he said, became a member of the Society in 1924 and, with Mr. Combs, helped greatly to organize the Canadian Section and has worked unremittingly in the interests of the Section. He is Vice-Chairman of the Transportation and Maintenance Committee of the Society.

As the speaker of the evening, Mr. Combs showed motion pictures that he had taken himself along the railroad, including views through the Canadian Rockies.

Transportation Engages Meeting of Kansas City Section

DINNER at the LaSalle Hotel, with C. F. Rouze, president of the Kansas City Motor-Car Dealers Association, as toastmaster, preceded the meeting of the Kansas City Section on Dec. 9. The attendance at the meeting was 34. An interesting feature of the session was a motion picture depicting the progress in various modes of transportation during the last decade and featuring the electric-driven truck.

Store-Door Delivery was the subject of the leading paper, which was presented by A. H. Gossard, of Chicago, vice-president of the Middle West Utilities Co. The Pickwick Van System was credited with the origin of this system, having coordinated canals and stages with vans and carts for service between English cities long before steam railroads existed.

About 95 per cent of all railroad tonnage has to pass over a highway during part of its travel. Improved roads have made it profitable to truck less-than-carload shipments up to distances estimated variously at 50 to 200 miles. Mr. Gossard referred to this business as the skimmed milk of the railroads and the cream of the motor-truck.

Shipping containers, according to the speaker, are frowned on by the Interstate Commerce Commission. He described a system, operated by a Mid-Western railroad, in which trailers are loaded by the shippers, hauled to the rail-head and loaded on special flat cars; and he referred to the production of containers weighing about one-third as much as steel containers, which can be pushed on or off a car by one man.

Railroads are producing transportation. If they do not find a way to deliver their product to the customer, Mr. Gossard believes that their sales will suffer just as would those of a merchant or manufacturer who could not deliver his product.

Changes in Tire-Servicing Problems was the subject discussed by the second speaker, J. W. Shields, of the field-engineering department of the Firestone Tire & Rubber Co. Among the prominent discussers of the papers were G. R. Gwynne, sales manager of the White Co.; R. H. Van Ness, transportation manager of the City Ice Co.; and Mr. Harbison, of the Transport Terminal Co.

Fishleigh Tells Philadelphians That Big Jobs Are Open

AT THE MONTHLY meeting of the Philadelphia Section on Dec. 9 Walter T. Fishleigh addressed the 69 members and guests in attendance on the subject, Big Jobs Are Open in Engineering Leadership. John A. C. Warner, General Manager of the Society, reported that the Council had directed the printing of S.A.E. TRANSACTIONS for 1930 and 1931 and the distribution of the volume without charge to members who desire the book.

More than 50 members were present at the dinner and entertainment preceding the technical session, and in the discussion on Mr. Fishleigh's paper those who took principal parts were B. B. Bachman, of the Autocar Co.; R. W. A. Brewer, consulting engineer; William J. Mayer, of the Edward G. Budd Mfg. Co.; and W. Lawrence LePage, of the Kellett Autogiro Corp. and Chairman of the Section. Norman G. Shidle, of the Chilton Class Journal Co., presided.

PRESENTATION OF LOVING CUPS AT CANADIAN SECTION MEETING

(Left to Right) Alexander S. McArthur, "Godfather of the Section"; George W. Garner, Section Chairman; Robert H. Combs, "Father of the Section"; and Warren Hastings, Section Secretary.

Detroit Holds Aeronautic Dinner

AIR TRANSPORT Ignores the Depression, according to Carl B. Fritsche's headline at the Book-Cadillac in Detroit on Dec. 7. Preceding the Section dinner, decorated by Finzel's orchestra, was a technical session beginning at 5.15, at which Edward T. Vincent read a paper on Diesel engines. Mr. Vincent, who is Diesel research engineer of the Continental Motors Corp., is of English origin and gained

most of his experience in connection with submarine work for the British Admiralty and in developing the Beardmore high-speed Diesels for rail-cars. The meeting was arranged by W. S. Pritchard, vice-chairman of the Aeronautic Activity, and his assistant vice, R. N. Dubois.

Unavoidable shrinkages in estimates, inventories and capital values have come to the aircraft industry as to others, according to Mr. Fritsche, who professed confidence in its future because the industry is based on a scientific foundation that is worthy of public respect and the realization that success must be built on the same economic principles as in more prosaic fields of business. The very youthfulness of the industry should speed its recovery when the trend of business starts upward again, provided it has been completely deflated to a common-sense basis.

Production of military airplanes has been maintained during 1930 and 1931, but commercial production has fallen off badly. Meanwhile, increases have been registered each year in passenger traffic, air mail and air express, some of them being more than doubled. These increases are the more significant in view of the decreases experienced in other forms of transportation. Purchases of airplanes by transport companies should make 1932 a more profitable year for the manufacturers, in Mr. Fritsche's opinion. The McNary-Watres Act and the consequent remapping of the airways of the Country are credited with contributing much to the increase in the use of air transport.

Transoceanic airships are the hope of foreign commerce, remarked Mr. Fritsche, who looks for the passage of a merchant airship bill by the present Congress. Freight-train speed is now the limit of foreign travel and transport. Speeding this transport will greatly aid international commerce, and foreign trade and shipping are said by some economists to provide work normally for one in ten of our citizens.

Dayton Section Addressed by W. B. Stout

JOHN PUBLIC'S Airplane was the subject chosen by W. B. Stout for presentation to 250 members and guests at the technical session of the Dayton Section, held Dec. 8 at the Engineers' Club. Preceding the session, a dinner was served, at which 30 diners partook of venison provided by G. W. Frank, Vice-Chairman of the Section.

Increased use of the airlines as a means of transportation and the extension of these lines were discussed by Mr. Stout, who said also that among its requirements a privately owned airplane should have an appealing design, a quality which the American public demands, and be as nearly foolproof as possible. He then described features of the Stout Sky Car, in which he flew from Detroit to Dayton.

The pilot's seat is placed so that, when the plane is grounded, the level of the pilot's eyes is about the same as it would be if he were walking. The average man is a poor judge of vertical distances, and this was done so that he can gage the plane's height better while landing. In addition to the regular landing-wheels, a fourth wheel is installed under the nose. This wheel prevents the plane from nosing over while landing. If the stick is pushed forward when landing until the front wheel touches the ground, the lift on the wings is zero. This throws the entire weight of the plane on the wheels and gives maximum braking effect.

Visibility is greatly increased by mounting the engine at the rear, and this also keeps the propeller airstream and engine fumes from the cabin. The relative merits of slow and moderate landing speeds were explained by Mr. Stout, who showed motion pictures of the airplane in flight and in various maneuvers.

High-Compression Engines and Fuels

THE PROBLEMS of high-compression engines and satisfactory fuels for them were discussed in a paper presented by Charles D. Hawley, of the engineering laboratory of the Ethyl Gasoline Corp., before 20 members of the St. Louis Section assembled at the Engineers Club on Dec. 8. The address was illustrated with many lantern slides of graphs, indicator cards from Otto and Diesel-cycle engines, drawings of exhaust valves and polar diagrams of bearing loads.

Two Papers at St. Louis Meeting

BEFORE a gathering of 57 members and guests of the St. Louis Section in the Coronado Hotel on Nov. 17 Newton F. Hadley gave a paper describing the engine suspension of the Plymouth cars whereby the communication of vibration from the powerplant to the chassis is prevented. The author is chief engineer of the Plymouth division of the Chrysler Corp.

A second paper, entitled Commercial Aviation and Its Development, was presented by W. H. Hottel, manager of the Transcontinental & Western Airlines.

Eighteen members were present at the dinner that preceded the technical session.

Oils and Safe Trucking

TWO SUBJECTS were presented and motion pictures of a working display of electric brakes were shown at the monthly meeting of the Oregon Section at the Multnomah Hotel in Portland on Dec. 4. S. C. Schwarz, chemical engineer of the Portland Gas & Coke Co., told the story of the production, properties and reclamation of mineral lubricating oils, and Lew Russell, of the Consolidated Auto Freight Lines, gave a talk on safety in truck transportation as effected by his company, which operates from Portland to Boise, Idaho; Spokane, Wash.; and to the Oregon-California State line. Prominent among the discussers of the topics were Fred Dundee, Harley Drake and James Cassell.

Twenty-seven members and guests were present at the dinner and 38 at the technical session. The Sunset Electric Co. supplied radio entertainment during the dinner.

Transmission Developments Told at Indiana Session

SO MUCH interest was stimulated by the papers on transmissions presented at the Dec. 10 meeting of the Indiana Section that discussion continued for 1½ hr. and had to be stopped by the Chairman after it had extended well past the usual time limit of the meetings. Fifty-two members and guests were present for the dinner in the Hotel Severin roof garden, and 160 attended the technical session.

Modern Automobile Transmissions was the title of a paper delivered by Samuel O. White, chief engineer of the Warner Gear Co.; and Perry L. Tenney, chief engineer of the Muncie Products Division of the General Motors Corp., gave a talk on Recent Developments in Transmissions and Reasons for Present Types and Trends. Although neither paper was illustrated, the speakers held the close attention of their audience and evoked lively and prolonged discussion in which a leading part was taken by William G. Wall, Fred S. Duesenberg, H. M. Jacklin, Louis Schwitzer, Harold Caminez and William B. Barnes.

Much of Mr. White's paper was devoted to discussion of the free-wheeling transmission in which the overrunning clutch was placed between the two top speeds and operated by the conventional control lever, eliminating the need for an extra lever and an extra operation for reversing, the control lever having a top thumb-latch for locking the mechanism for positive action which is required by a number of States. Automatic declutching, especially of the vacuum-controlled type, is very much to the fore today, he said, but can hardly be regarded as a true free-wheeling mechanism.

As the public seems to want free-wheeling action for all speeds and the lock is used more than was expected, the overrunning clutch has been moved to the rear of the transmission, where it started, thereby affording free-wheeling at all speeds and easier locking for conventional driving for indefinite periods. This change led to the development of a simple gear synchronizer located between the two front pairs of gears to make conventional shifting easier and resulting in a transmission quite unlike any of two or three years ago. It combines in one assembly constant-mesh spiral gears that are engaged by individual clutches through the medium of a synchronizer, a free-wheeling clutch that is automatically controlled and convenient means for locking the device at the driver's option for conventional operation.

The January meeting of the Section is to be held at Purdue University in Lafayette, Ind., where the Section will cooperate in a two-day session on maintenance. No regular meeting is to be held, because of the automobile shows.

Joint Meeting on Welding in Cleveland

TWO PAPERS on welding were presented and discussed at a joint meeting on Dec. 14 of the Cleveland Section of the S.A.E. and the Cleveland Chapter of the American Society for Steel Treating. The meeting was the first held by the Section in the new Cleveland Club, the new meeting place of the Section, which is conveniently located in the eastern industrial and business district of the city. D. S. Cole, Vice-Chairman of the Section, introduced W. E. Benninghoff, Chairman of the steel treaters' chapter, who then served as chairman of the session. Eighty members of the two organizations were present for the dinner, at which entertainment was provided, and 100 more came later to hear the addresses and discussion.

The methods of joining metals and the apparatus used, as practiced by the General Electric Co., were described by L. D. Meeker, of the company, who stated that the principles for making successful welds are suitable design, control of the quantity of metal deposited and skill of the welder. Methods of testing welds were also mentioned.

W. S. Walker, of the Linde Air Products Co., discussed the Linde process of welding and showed motion pictures of the operation on a pipe line. The excellent close-up views of gas welding were very instructive. The new method of making heavy line-welds with a 70-deg. bevel on the butting pieces, using a combination torch that preheats the welding rods before it reaches the welding frame, was shown to be very effective. Close-up views clearly illustrated the action of the flame, the molten rod and the butting pieces, as well as showing how the materials should be handled by the operator.

The Lindeweld pictures aroused considerable discussion by members and guests. Regarding welding in general, J. C. Lincoln, of the Lincoln Electric Co., agreed that the chief requirements for producing good welds are right design of the weld and skill or training of the welder, who should be a specialist.

Diesel Engines and Ignition

NORTHWEST Section members to the number of 57 gathered at the New Washington Hotel in Seattle on Dec. 4 to hear two speakers, and most of them participated in the discussion of the subjects presented. Twenty-seven attended the members' dinner that preceded the technical session.

A paper on Diesel Engines was delivered by James H. Frink, of the Washington Iron Works, and Reese Lloyd, superintendent of the Sunset Electric Co., gave one on High-Speed Ignition.

Ohio U. Student Branch

ABOUT 50 members and prospective members of the Ohio State University Student Branch of the Society met in Columbus on Nov. 17 and heard an interesting discussion by Lieutenant LeMay, U. S. A., on The Development of Army Pursuit Planes and Tactics. The Branch is considering the question of sending a delegate to the Annual Meeting in January.

New Developments in Lubricants

IN A PAPER presented at the meeting of the Indiana Section on Nov. 19 at the Hotel Severin in Indianapolis, R. E. Wilkin, sales engineer of the lubricants division of the Standard Oil Co. (Indiana), explained the recent developments in rear-axle and transmission lubricants for heavy tooth-pressure service. Discussion of the subject was participated in by numerous members, among whom were F. S. Duesenburg, William B. Barnes, Chester S. Ricker, O. F. Fishburn, C. A. Trask, George Freers, Lee Oldfield, H. M. Jacklin and C. L. Cummins.

The meeting was well attended, 135 members and guests being present at the technical session, which followed a members' dinner of which 50 partook.

Canadians Told that Industry Needs Master Plan

DRAWING a moral from the present period of depression, W. Eric Harris, resident manager of Electric Auto-Lite, Ltd., of Sarnia, Canada, speaking at the Dec. 16 meeting of the Canadian Section, at the Royal York Hotel in Toronto, said that the industry's task during the coming years will be to stabilize itself so that a recurrence of present conditions will be impossible. He said further, in part:

I believe that the efficiency of industry can be so increased that it will, to a great extent, be able to absorb its unemployment. Industry, however, must revamp its present idea of responsibility toward its workers. Business will find, more and more, that chief emphasis must be placed on its employes, as part and parcel of the great consuming market of the Country, rather than upon the piling up of profits for shareholders. Protection of the workers and security of employment, as well as an assurance of permanent income to investors, must become a basic purpose of industry everywhere. There should be a master plan to guide and control the growth of a business, just as there should be a plan for the proper development of a city.

Mr. Harris pointed out that during the last ten years mass production attained full growth and influence, with fewer men turning out more goods. For a long time this displacement of men did not have any great effect because new industries were springing up to absorb these victims of efficiency. However, the time came when lack of important new inventions and the erection throughout the world of nationalistic barriers to international trade began to decrease the demand and opportunities for workers. Gradually, technological and managerial progress let loose so many workers that they could not be absorbed in other ways. That is no argument against efficiency; progress must continue. Industry, however, must attack this problem of unemployment.

A master plan covering all industries, which will reduce the peaks of prosperity to fill up some of the valleys of depression, is desirable to give the worker a feeling of security and, as a result, a steady market for the products of industry.

George W. Garner, chief engineer of General Motors of Canada and Chairman of the Section, presided at the meeting. Following the address by Mr. Harris, the members gathered in an adjoining room for Christmas-tree festivities. Each member received some novelty handed out by Santa "McGillivray" Claus, in addition to an ash tray presented through the courtesy of the Firestone company. Four members were also the lucky winners of turkeys in a draw. The Auto-Lite company acted as host for the evening, which all agreed was a huge success.

"Floating Power" Described at Buffalo

AT THE JOINT meeting held in the terrace room of the Hotel Statler on Dec. 8 by 66 members and guests of the Buffalo Section of the S.A.E. and the American Society of Mechanical Engineers, N. F. Hadley, chief engineer of the Plymouth division of the Chrysler Corp., delivered his paper on Floating Power, which was followed by four reels of "talking" motion pictures and a demonstration of a working model.

Among the prominent discussers were W. R. Gordon, of the Truck Equipment Co., Inc., Buffalo; L. P. Saunders, of the Harrison Radiator Co., Lockport, N. Y.; W. H. Schaefer, of the Goodyear Tire & Rubber Co., Buffalo; and J. L. Harrington, past-president of the American Society of Mechanical Engineers.

How Connecticut Controls Aviation

CONNECTICUT led all other States in giving attention to the control of aviation by enacting a law on the subject in 1911, asserted George P. Kane, chief inspector of the Department of Aeronautics for the State, at a meeting of the New England Section on Dec. 16. The meeting was held at the Massachusetts Institute of Technology in Cambridge, Mass., with about 50 members present. An interesting feature of the session was the showing of motion pictures of Navy aviators in training and in maneuvers with the fleets.

Administration of the State law governing aviation was first under the Secretary of State, then the Motor Vehicle Department, and now is assigned to a distinct department. The work is handled by a commissioner and his deputy, two flight sergeants, three inspectors and a corps of clerical workers, and the department is provided with three airplanes.

The State is noted for the strictness of its examinations of machines and pilots, said Mr. Kane, and carefully checks up on them. Doctors trained in aviation work must pass upon applicants for licenses, and airplanes are

examined regularly. When one is involved in an accident, it is carefully inspected before being allowed to fly again. As a result, only three Connecticut-licensed pilots have figured in fatal accidents in nine years, out of 13 fatal crashes that occurred in the State.

Army Equipment and Knock-Testing Engine Featured

THE JOINT meeting held Dec. 2 in Milwaukee was another record breaker, there being 133 at the dinner and a total attendance of 231. The Milwaukee Post of the Army Ordnance Association cooperated with the Milwaukee Section of the Society. Chairman H. L. Debbink introduced A. J. Underwood, director of Sections Activities of the Society, and then turned the meeting over to Past-President H. L. Horning, who introduced the speakers. Capt. Stewart E. Reinel, of the United States Army Ordnance Department at the Rock Island Arsenal, ably substituted for Major L. H. Campbell, Jr., who was originally scheduled.

Army Automotive Equipment Discussed

On the subject of Automotive Equipment for the United States Army, Captain Reinel said in part that the main reason for using it in the Army is the conservation of soldier energy for front-line work by eliminating wasted man-power in transportation and incidental activities. He stated that current engine, truck and tractor design are employed when feasible. Lantern slides of trucks, tanks, tractors, trailers, reconnaissance cars and combat cars were shown. To illustrate the problems for the man behind the man behind the gun, he mentioned the extremes of weight, of speed, and of the duties required of the automotive equipment, citing the Ford cross-country car, six-wheel trucks, 5-ton caterpillar tractors, 50-ton tanks and the 75 and 155-mm. (2.95 and 6.10-in.) guns mounted on trailers and also self-propelled, stating also that these, respectively, are capable of maintaining road-speeds of 40 to 67 m.p.h. and also can travel at high speed across country.

According to Captain Reinel, among the Army's current problems is a decision on whether to use more speed and less armor, as advocated by the British, or heavier armor and lower speeds, according to French practice. He said that the mounting of the heavier guns on trailers instead of transporting them as self-propelled units is now advocated. W. W. Coleman, president of the Bucyrus-Erie Co., agreed with Captain Reinel in advocating that sufficient funds be obtained for this work so as to reduce the ultimate cost in the event of a National emergency.

Engine Demonstration Made

Chairman Horning then introduced Arthur W. Pope, Jr., research engineer for the Waukesha Motor Co., who demonstrated the fuel-knock testing-engine which resulted from studies made by the Cooperative Fuel-Research Committee. The details of this engine have been published[1]. It was shown in operation and described by Mr. Pope, who said in part that the stamina of this test engine for continuous duty and the measuring of knock-intensity will greatly assist in the search for means by which more British thermal units from the fuel may be made available as energy at the flywheel. He illustrated by charts the octane numbers of various engine fuels from different sources, and both advocated and predicted the early marketing of fuel by octane numbers. Chairman Horning stated that recent octant-number test-data can be obtained from the American Petroleum Institute.

Among the prominent discussers were P. W. Eells, of the LeRoi Co.; C. E. Frudden, of the Allis-Chalmers Mfg. Co.; and H. L. Horning, president and general manager of the Waukesha Motor Co.

[1] See S.A.E. JOURNAL, June, 1931, p. 637.

Aviation's Future Considered

THE FUTURE of Aviation was the topic of an address made by Edward P. Warner, formerly Assistant Secretary of the Navy for Aeronautics and now editor of *Aviation*, at a meeting of the Wichita Section held on Nov. 27. The technical session was preceded by a members' dinner at the Hotel Lassen, which was attended by 54 members and guests, and 14 more came in later to hear the forecast made by the speaker regarding the industry in which most of the Section members are vitally interested.

Syracusans Hear Hadley

NEWTON F. HADLEY, chief engineer of the Plymouth division of the Chrysler Corp., was the speaker at the Dec. 9 meeting of the Syracuse Section, held at the Hotel Syracuse and attended by 61 members and guests. After the "floating power" principle and construction of the Plymouth was explained by the speaker, the subject was discussed by E. S. Marks, of Franklin; C. P. Grimes, of the Grimes Brake Service; and L. Stellman, consulting engineer.

Met. Section Holds a Diesel-Engine Session

DO WE NEED an Automotive Diesel Engine? was the provocative and interest-arousing title of a paper presented by Myron S. Huckle, instructor in aeronautic engineering at the Massachusetts Institute of Technology, before a gathering of nearly 250 members and guests of the Metropolitan Section on Dec. 17. The other speaker of the evening, H. L. Newton, an engineer of the Vacuum Oil Co., carried the memories of the old-time members back to early days in the automobile industry by means of lantern slides of the old Elmore two-cycle automobile and running comments on them.

The two addresses brought out a great deal of animated discussion in which the following took part: Joseph A. Anglada, Anglada Motor Co.; A. L. Beall, Vacuum Oil Co.; O. F. Allen, consulting engineer; Herbert Chase, consulting engineer; William E. John, Sterling Engine Co.; Lieut. R. F. Good, United States Navy Yard; F. C. Mock, Eclipse Aviation; J. M. Pratt, National Railway Appliance Co.; Julius Kuttner, Oberhaensli & Cie; W. A. Smith, Scarr Transportation Service; C. H. Schleisman, Standard Oil Co. of New York; Capt. W. C. Thee, U.S.A.; and G. Wirrer, International Motor Co.

Creamer Succeeds to Chairmanship

As usual, the meeting was held at the A.W.A. Clubhouse in New York City and was preceded by a members' dinner, at which the attendance was 141. At a short business session, announcement was made of the resignation of C. E. Hamilton as Chairman of the Section and the automatic succession of J. F. Creamer, president of Wheels, Inc., to the office and the appointment by the Governing Board of F. H. Dutcher as Vice-Chairman, Grosvenor Hotchkiss as Chairman of the Papers Committee, C. H. Baxley as Chairman of the Entertainment Committee and George Bock as a member of the Papers Committee.

Prof. C. E. Lucke, of Columbia University, presided at the technical session.

Diesel engineers could well derive fresh enthusiasm from Professor Huckle's paper, in which the author answered the question propounded in the title very much in the affirmative. His defense of the Diesel engine and the reasons advanced for needing it in automotive transportation on land and water and in the air shows him to be a strong proponent for this type of powerplant. He emphasized particularly the safety element inherent in the use of a non-volatile fuel and supported this by citing various authorities and some statistics of aircraft fires in the air and after crashes.

Combustion and Speed Solved

Combustion systems in Diesel engines were classified into five types, of which the Deutz and Benz systems, of a pre-combustion-chamber separated from the main cylinder by a relatively large orifice but embracing virtually all of the clearance volume, represent a type that, when designed to induce a high rate of turbulence, has exceeded in performance any other type. A change made in England to this system by the Associated Equipment Co., a subsidiary of the London General Omnibus Co., is reported to have increased the brake horsepower from 95 to 140 at 2500 r.p.m., 9 of the 45 additional horsepower being attributed to a slight increase of cylinder bore.

Speed limitation no longer retards correctly designed Diesel engines, some of which have been operated at 4000 r.p.m., said Professor Huckle. Only the dynamic problems persist, and the reciprocating weights are but little greater than those in the Otto-cycle engine. The structural problem is relatively simple; a high-speed Diesel can be designed to work at a maximum pressure of 650 to 900 lb. per sq. in., which com-

pares with 750 lb. in modern aircraft engines.

The greatest potential field for the aircraft Diesel was said to be in airships for long non-stop routes; a 20 per cent fuel saving would increase the range of the Akron to 12,700 miles or allow an increase of 35.7 tons in payload or 186 passengers on a distance of 10,580 miles.

Sufficient knowledge has been available in this Country for several years to build a successful high-speed Diesel engine, asserted the speaker, who suggested that a pooling of engine-designing ability similar to that which resulted in the Liberty engine might be undertaken.

Robert C. Hupp

CEREBRAL hemorrhage caused the sudden death on Dec. 7 at the Detroit Athletic Club of Robert C. Hupp, a pioneer automobile designer and manufacturer whose name is perpetuated in the Hupp Motor Car Co. and the Hupmobile. During the years 1908 to 1911 Mr. Hupp directed the designing of and built the first Hupmobile, a small, light car, and promoted its production and sale.

Most of Mr. Hupp's business life had been devoted to the automobile industry and he had been a member of the Society for the last 10 years. Born at Grand Rapids, Mich., in June, 1877, he attended the Detroit High School and the Detroit Art School of Design. After spending some time in the chemical, coal and railroad freight businesses, he went to work in 1902 for the Olds Motor Works in the early days of the little single-cylinder curved-dash Oldsmobile runabout. During three years' connection with this company he served in all shop and office departments and became manager of service. The next three years were spent with the Ford Motor Co., as manager of service and accessories and as assistant to the production superintendent on six-cylinder cars. Next Mr. Hupp spent half a year in designing and promoting the Regal car for the Regal Motor Car Co. Then followed his work on the Hupmobile, after which the years 1911 to 1913 were devoted to the designing and building of the Hupp-Yeats electric car and the R.C.H. cars and those from 1913 to 1916 to similar work with the Monarch Motor Car Co. In the succeeding eight years he brought out three cars for other companies as a consulting automotive engineer in Detroit. In 1924 he served as assistant general manager of the Hydraulic Brake Co., of Detroit; and from 1926 to the time of his death, Mr. Hupp was engaged most of the time in automotive development engineering in Detroit and later in Birmingham, Mich.

Reno Haibe

AFTER a cessation of work since the middle of last January because of heart trouble, Reno Haibe, service foreman for Lathrop Moyer Retail, Inc., of Indianapolis, passed away on Oct. 22.

Mr. Haibe, who was elected a Member of the Society in March, 1921, had devoted his entire professional life to the motor-vehicle industry. Born at Indianapolis in 1883, he began work as an engine assembler for the Maxwell-Briscoe Co., at New Castle, Ind., in 1906. Thereafter he was successively parts inspector for the Stoddard-Dayton Motor Car Co., of Dayton, Ohio; engine assembler for the Empire Motor Car Co.; road tester for the Motor Car Mfg. Co.; engine assembler and inspector for the Federal Motor Works; road tester for the Cole Motor Car Co., all of Indianapolis; and foreman of block and road tests for the Kissel Motor Car Co., of Hartford, Wis. During his connection with the last named company from 1913 to 1923, he served also as chief inspector and research engineer.

In 1923 Mr. Haibe returned to the Cole Motor Car Co. to perform service work, and from that time remained in the service field, successively as service representative for the Olds Motor Works, of Lansing, Mich., and then as sales promotion manager for the Lathrop McFarland Co. in Indianapolis, which subsequently became the Lathrop Moyer Co. and Lathrop Moyer Retail, Inc.

Harry Lee Stivers

INFORMATION has been received from the Bell Telephone Co. of Pennsylvania that Harry Lee Stivers, division motor-vehicle supervisor for the company, passed away in November.

Mr. Stivers, who was elected an Associate Member of the Society in 1930, was born at Miners Mills, Pa., in 1894 and had been engaged in the automobile industry for nearly 20 years. For five years from 1912 he was a repair man for the Packard Motor Car Co. in Chicago and Boston. In 1917 he entered the military service as civilian truck master in the Quartermaster Department, supervising operation and maintenance of Army truck trains on the Mexican border. The following year he was commissioned a first lieutenant in the Motor Transport Corps and commanded a mobile repair-shop unit in the American Expeditionary Force. After the World War he was for nearly four years service manager for the Citizens Motor Co., of Wilkes-Barre, Pa., and from 1922 to 1928 was proprietor of the Jordan Garage & Accessory Co., of the same city. His service with the Bell Telephone Co. began four years ago and continued up to the time of his death.

Arthur D. Hoge

TOGETHER with four companions, Arthur D. Hoge, president of the Hoge Piston & Ring Co., Inc., of Seattle, Wash., met his death recently in an airplane crash in Snoqualmie Pass while returning from a hunting trip. The Northwest Section of the Society, of which Mr. Hoge was a member, voted at its November meeting to send an expression of its deep regret and sympathy to Mr. Hoge's family.

Since serving in the Army Air Service and Army Transportation Service from 1917 to 1919, Mr. Hoge had devoted his efforts to the wholesaling of automotive parts in Seattle. He was born at Cavalier, N. D., in August, 1896, and received his higher education at the University of North Dakota. He was admitted to Associate Grade in the Society in December, 1928, at which time he was manager of the Hoge Piston & Ring Co. The following year he became president of his company.

Earl H. Hecht

FOLLOWING an illness lasting five weeks resulting from an infection, Earl A. Hecht, layout engineer with the Westinghouse Electric & Mfg. Co., in Mansfield, Ohio, passed away at his home there on Dec. 6.

Mr. Hecht had been a member of the Society since 1918 and was also a member of the Tire & Rim Association. Born at Mansfield in 1892, he was employed as a draftsman successively from 1908 to 1913 by the Ohio Brass Co., Aultman & Taylor, the B. F. Seibert Co. and Vernon Redding, architect, all of Mansfield, on automobile parts, gasoline tractors, Patent Office drawings and factory, hotel and residence buildings. For five years he was a designer of machinery and equipment for the Mansfield Tire & Rubber Co.; from 1920 to 1929 was mechanical engineer and later chief engineer of the Columbia Tire & Rubber Co., of Mansfield; and in 1929 joined the Westinghouse company in the capacity of layout engineer.

Chester M. Angell

WITH great regret the Vesta Consolidated Corp. recently announced the death of the president of the corporation, Chester M. Angell, on Sept. 29.

Mr. Angell was elected to Member grade in the Society in 1929. He had been actively engaged in the industry for 15 years, having been sales manager of the El Camino Real Garage Co., of Santa Barbara, Calif., in 1915 and manager of the storage-battery department of the Auto Equipment Co., of Denver, Col., in 1916. The following year he joined the Vesta Battery Corp., of Chicago, and for three years devoted his attention to laboratory work. He was then made production manager, and in 1922 was appointed battery engineer. In 1927 he was elected vice-president in charge of production and research, and subsequently was elected president of the corporation.

Mr. Angell was born at Omaha, Neb., in 1885 and attended the Manual Train-

(*Concluded on p.* 36)

Personal Notes of the Members

S.A.E. Members Head Rockne Motors

The new Rockne Motors, which made its debut in December with the announcement that the company is backed by the Studebaker Corp. and the car was named for Coach Knute Rockne, is officered largely by members of the Society. Albert R. Erskine, president of the Studebaker Corp. and of the Pierce-Arrow Motor Car Co., who is chairman of the board of directors of the Rockne Motors, has been a member since 1922. Harold S. Vance, president of the new company and vice-president of Studebaker, in charge of manufacturing and engineering, has been an S.A.E. member since 1927. Ralph A. Vail, vice-president in charge of production and formerly engineer of the Vail-Cole Engineering Co., of Detroit, joined the Society 22 years ago. Roy E. Cole, chief engineer of the organization, who was formerly a partner in the Vail-Cole company, was elected a member in 1928.

Both Mr. Cole and Mr. Vail were associated with Dodge Brothers in Detroit prior to 1930, the former as director of engineering and the latter in the manufacturing department. Later both joined Durant Motors, in Lansing, Mich., Mr. Vail becoming vice-president in charge of engineering and manufacturing and Mr. Cole chief engineer. In the latter part of 1930 they joined forces and formed the Vail-Cole Engineering Co.

Although never a member of the Society, Knute Rockne will be remembered not only for his remarkable success as coach of the Notre Dame football eleven but as the very happy selection as speaker at the S.A.E. Annual Dinner in January a year ago, only a few months before his deplored death in an airplane crash in the Southwest. Mr. Rockne had been associated with the Studebaker Corp. for several years and was to retire from active football direction at the end of the 1931 season and become vice-president of Rockne Motors.

The new Rockne Six, on which production started in December, is being manufactured in Detroit in the plants formerly occupied by the Studebaker Corp. for part of its production.

Paul Weeks Becomes Washington Manager

Among several personnel changes announced by B. C. Heacock, president of the Caterpillar Tractor Co., is the transfer of Col. Paul Weeks from his post as general service manager at Peoria, Ill., to that of manager of the company's office in the City of Washington.

Colonel Weeks, who became a member of the Society in 1913, has devoted his professional life to transportation and road-building machinery since being graduated with the degree of Bachelor of Science by the University of Nebraska and taking the post-graduate course in mechanical engineering at the Massachusetts Institute of Technology. After an apprentice course in the shops of the Baldwin Locomotive Co., he was made successively shop foreman, engineer of tests and then mathematician in the design department.

At the time of joining the Society, Colonel Weeks was a mechanical engineer in Los Angeles, where he invented and built the Weeks orchard tractor, and in 1911 cast his lot with the Holt Mfg. Co., of Stockton, Calif. When the United States entered the World War, he was appointed a captain in the Ordnance Department of the Army in the City of Washington, where he was engaged in the designing and production of military tanks, tractors and trailers. Later he was commissioned a major and for a time had charge of the tank, tractor and trailer division. After his discharge from the service, he returned to the Holt Mfg. Co., as experimental engineer.

In 1921 he went to the Aberdeen Proving Ground of the Ordnance Department as automotive engineer and was commissioned lieutenant-colonel in the Ordnance Reserve, a commission he still holds. Three years later he returned to civil work as chief engineer and service manager of the American Car & Foundry Motors Co., in Detroit, and the following year was made general service manager of the Caterpillar Tractor Co.

Besides holding membership for nearly 20 years in the S.A.E., Colonel Weeks joined the American Society of Mechanical Engineers and the American Society for Testing Materials about the same time.

Upson with Automotive Fan & Bearing Co.

Ralph H. Upson, who has been engaged for some time in the development of a novel airplane-flying instrument that combines the functions of several present instruments, is associated with the Automotive Fan & Bearing Co., of Jackson, Mich. He is not yet ready to give the scientific and engineering details of the instrument, which he described in general terms at the October meeting of the Indiana Section, but promises to give a paper on the subject at a forthcoming National meeting.

After his highly successful design work in 1926 and 1927 on the experimental metalclad ZMC-2 airship built for the Navy by the Aircraft Development Co., of Detroit, Mr. Upson was engaged in aeronautic engineering with the Aeromarine Klemm Corp., of Keyport, N. J., in 1929, following which he spent the last two years in development work on a new type of airplane and the new airplane instrument at the Stout Engineering Laboratories in Dearborn, Mich. The results of this recent work have now taken concrete form and are approaching the stage of commercial production.

Dr. Bridgeman Made Section Chief

Dr. O. C. Bridgeman, who is well known to members of the Society for his extensive work in the cooperative fuel research, was recently appointed chief of the friction and lubrication section of the Bureau of Standards in the City of Washington. His former position was that of research associate.

Through his work in recent years Dr. Bridgeman has become known internationally as an outstanding authority on volatility and vapor-lock properties of gasolines and on determination of the gum content and other characteristics. He is a native of Canada but became a citizen of the United States in 1930. He holds the degrees of Bachelor of Arts in chemistry and mathematics and Master of Arts in chemistry from the University of Saskatchewan, and Doctor of Philosophy in physical chemistry from Harvard University, and from 1925 to 1927 studied physics at the Massachusetts Institute of Technology. He also had two years' teaching experience in the University of Alberta. He was research associate of the Bureau of Standards from September, 1927, until his appointment last September as chief of the friction and lubrication section. During these four years he has been engaged in supervising and conducting research on problems for the automotive and petroleum industries.

Dr. Bridgeman was admitted to Member grade in the Society in January, 1930, and was transferred the following April to Service Member grade. Many of his research papers have been published in the S.A.E. JOURNAL and other technical periodicals.

Ingalls Joins Aviation Foundation

Following the recent announcement that the Shriners of North America had decided to form the Aviation Speed Foundation with the object of furthering the development of airplanes and seaplanes capable of bringing to America the world air-speed records, the chairmanship of the board of directors of the new Foundation has been accepted by the Hon. David S. Ingalls, Assistant Secretary of the Navy for Aeronautics. The objective of the Foundation is to raise a fund of $16,000,000 for the purpose stated. Mr. Ingalls became an Associate Member of the Society in 1929 and has taken an active part in several National meetings of the Society.

E. L. Cord Resumes Auburn Presidency

E. L. Cord has again resumed the presidency of the Auburn Automobile Co., following a brief vacation begun early last summer. In returning to active management of the company, Mr. Cord stated that he was carrying

(*Continued on p.* 52)

Applicants for Membership

The applications for membership received between Nov. 16 and Dec. 15, 1931, are listed below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ANTHONY, RICHARD L., instructor in mechanical engineering, Yale University, *New Haven, Conn.*

BLADES, STANLEY ROBERT, engineer, Automotive Products Co., *London, England.*

CUMMINGS, EVERETT D., branch manager, International Harvester Co. of America, *Baltimore.*

DOWD, RAYMOND E., aeronautic engineer and automotive representative, Russell Mfg. Co., *Chicago.*

FORD, STUART M., vice-president and general manager, Collins & Aikman of Canada, Ltd., *Farnham, Que., Canada.*

FRUHWIRTH, ADOLF EDWARD, chief chemist, Vacuum Oil Co., Inc., *Cairo, Egypt.*

HAISS, R. C., vice-president and general manager, George Haiss Mfg. Co., *New York City.*

HARLEY, STANLEY J., deputy managing director, Coventry Gauge & Tool Co., Ltd., *Coventry, England.*

HILL, EDWARD B., branch manager, Wood Hydraulic Hoist Co., *Seattle, Wash.*

ITO, TAKASHI, assistant designer, Tokyo Gas & Electric Engineering Co., Ltd., *Tokyo-shi, Japan.*

JEFFERSON, THEODORE BREWSTER, operations manager, Missouri Valley Aero Club, *Kansas City, Mo.*

JORGENSEN, N. A., branch manager, Wood Hydraulic Hoist & Body Co., *Chicago.*

JOYS, ROBERT BROWNELL, manager, New York branch, The Heil Co., *Long Island City, N. Y.*

KILDUFF, FRANK B., production manager, Oriental Textiles Co., *Oshawa, Ont., Canada.*

KOHLSTRAND, EDWARD A., minor layout, Hudson Motor Car Co., *Detroit.*

KYLE, W. A., salesman, Valspar Corp., Ltd., *Walkerville, Ont., Canada.*

PATCHETT, ULYSSES A., instructor in mechanical engineering, *Stanford University, Calif.*

PATZIG, GUIDO HEINRICH ALFRED, chief engineer, Wanderer Werke A/G, *Chemnitz, Germany.*

PAWLOWSKI, FELIX WLADYSLAW, professor of aeronautics, University of Michigan, *Ann Arbor, Mich.*

PRICE, GUY WILLIAM, manager, brake department, Goodyear Service, Inc., *Los Angeles.*

ROCHFORD, ALAN V., vice-president, T. Rochford Sons, Inc., *Brooklyn, N. Y.*

STANFORD, KENNETH J., partner, Kenneth J. Stanford, *New York City.*

WHITCOMB, JOSEPH CARLTON, assistant engineer, Maxim Motor Co., *Middleboro, Mass.*

WOERNER, ERNEST M., student engineer, Caterpillar Tractor Co., *Peoria, Ill.*

VOYCE, WILLIAM E., JR., proprietor, Voyce Motor Co., *Baltimore.*

Obituaries

(*Concluded from p. 34*)

ing High School in Denver and Colorado College in Colorado Springs. Besides his membership in the S.A.E., he was a member of the Society of Industrial Engineers.

J. William Schatz

AFTER 36 years spent in the manufacture of hardware, ball bearings and automobile parts, J. William Schatz met death in his home in Poughkeepsie, N. Y., Dec. 20, at the hands, it is believed, of a butler whom he had discharged the night before.

Born in New Haven in 1874, Mr. Schatz was associated first with Adolph Schatz and the Schatz Hardware Mfg. Co. When elected to membership in the Society, in 1913, he had had experience along commercial and technical lines in making tools for and manufacturing balls, ball bearings and automobile parts, and was the vice-president and superintendent of the Schatz Mfg. Co., in Poughkeepsie. Among his later activities was the production, at this plant, of one of the earliest of the modern type of motorcoach chassis.

Mr. Schatz was still vice-president of this company at the time of his death. He was also president of the Federal Bearings Co., of Poughkeepsie, and vice-president of the Waterbury Steel Ball Co., of Waterbury, Conn. Two of Mr. Schatz's brothers, one of them a member of the Society, were associated with him in business.

Applicants Qualified

The following applicants have qualified for admission to the Society between Oct. 10 and Dec. 10, 1931. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate; (S M) Service Member; (F M) Foreign Member.

BALDRIDGE, DALE D. (A) manager, service and maintenance departments, Jensen Brothers Garage, *Gustine, Calif.;* (mail) P. O. Box 118.

BARRIE, JOHN G. (J) instructor, mechanical engineering, New York University, College of Engineering, New York City; (mail) 23 Hancock Avenue, *Yonkers, N. Y.*

BARTON, CYRIL HENRY (F M) chemist. Asiatic Petroleum Co., Ltd., St. Helens Court, *London E. C. 3, England.*

BAUER, EDWARD LOUIS (A) assistant superintendent, in charge of maintenance, Municipal Garage, *St. Louis;* (mail) 8526 Park Lane.

BERRY, BYRON CONRADE (A) manager, B. C. Berry & Co., *Toronto, Ont., Canada;* (mail) 468 Grace Street.

BOESSENKOOL, JOHAN (A) automotive fleet maintenance manager, Curacaosche Petroleum Industrie My., *Curacao, Dutch West Indies;* (mail) de Barak, Emmastad.

BOUIS, C. M. (A) salesman, The White Co., 2401 Archer Avenue, *Chicago.*

BOYER, GEORGE HEWITT (A) manufacturers service division engineer, Vacuum Oil Co., Inc., 907 South First Street, P. O. Box 553, *Milwaukee.*

BRINK, ERNEST HAROLD (M) instructor, mechanical engineering, Lehigh University, Packard Laboratory, *Bethlehem, Pa.*

BROMBACHER, WILLIAM GEORGE (S M) chief, aeronautic-instruments section, Bureau of Standards, City of Washington; (mail) 6314 Ridgewood Avenue, *Chevy Chase, Md.*

BROWN, A. GEORGE W. (M) automotive engineer, Borden's Farm Products Co., Inc., 110 Hudson Street, *New York City.*

CRIDLAND, GEORGE ERNEST (A) manager service division, Roy Howard, Ltd., 849 Hornby Street, *Vancouver, B. C., Canada.*

DALLAS, ALLEN W. (J) structural engineer, Verville Aircraft Co., *Detroit;* (mail) 1304 Rademacher Avenue.

DAVIDS, JOHN (J) layout man, Johnson Motor Co., *Waukegan, Ill.*

DAVINE, J. L. (A) sales representative, Ethyl Gasoline Corp., 20 Providence Street, *Boston.*

DE KUZMIK, PAUL (M) divisional engineer, Pan American Airways, Inc., 122 East 42nd Street, New York City; (mail) Panair Do Brasil, Edificio Noite, 11 Andar, *Rio de Janeiro, Brazil.*

DUNLAP, KENNETH E. (M) direct factory representative, field engineer, Cleveland Universal Jig Co., Cleveland; (mail) 2-218 General Motors Building, *Detroit.*

FALLER, RAYMOND R. (J) automotive engineer, Ethyl Gasoline Corp., *Dayton, Ohio.*

GEARHART, ELDON D. (A) engineer, manufacturers' service division, automotive department, Vacuum Oil Co., Inc., New York City; (mail) 927 Linden Avenue, *Drexel Hill, Pa.*

GILMORE, A. FOSTER, CAPT. (S. M.) student, Harvard Business School, *Cambridge, Mass.,* (mail) 250 Brattle Street.

GOLIAEFF, D. V. (F M) Amazavod, *Moscow 68, U. S. S. R.*

GROSS, RUSSELL R. (M) factory manager, Firestone Tire & Rubber Co., Firestone Park, *Akron, Ohio.*

HALSEY, MAXWELL NICOLL (J) traffic engineer, National Bureau of Casualty & Surety Underwriters, 1 Park Avenue, *New York City.*

HARRAH, CLAYTON C. (M) pneumatic-tire engineer, National Standard Co., *Niles, Mich.;* (mail) 615 Main Street.

HARRIS, ELWOOD K. (J) instructor, drawing and design department, General Motors Institute of Technology, Chevrolet & Third Avenues, *Flint, Mich.*

HASKELL, A. (A) sales, Calumet Refining Co., Chicago; (mail) 1167 Laurel Avenue, *St. Paul, Minn.*

JOHNSON, JOSEPH BLAINE (M) chief engineer, assistant general manager, Bryant Chucking Grinder Co., 257 Clinton Street, *Springfield, Vt.*

KEARNEY, LAWRENCE J. (A) in charge of templet layout for die construction, Fisher Body Co., *Detroit;* (mail) 5510 Pacific.

KNOTT, ERNEST WALTER (F M) assistant chief engineer, Stromberg Motor Devices, Ltd., Bendix Works, Birmingham, England; (mail) 54 Ravenscroft Avenue, *London, N. W. 11, England.*

KNOWLES, RICHARD C. (J) instructor, Pratt Institute, School of Science and Technology, *Brooklyn, N. Y.*

KRONPRINZ AKTIENGESELLSCHAFT FUR METALLINDUSTRIE (Aff.) Postfach 165, *Solingen-Ohligs, Germany;* Representative: Boehm, H. W., director.

KUPEL, JOHN M. (M) general superintendent, Little Giant Products, Inc., *Peoria, Ill.;* (mail) Hotel Metzger, 214-220 North Adams.

KUTTNER, JULIUS (M) editor, *Diesel Power,* 192 Lexington Avenue, *New York City.*

LADD, HARVEY D. (A) service manager, Kenworth Motor Truck Corp., *Seattle, Wash.;* (mail) 1628 North 53rd Street.

LOCKE, ARTHUR A. (M) development and plant engineer, Wolverine Tube Co., *Detroit;* (mail) 1601 Clark Avenue.

MCINTOSH, LYMAN (M) sales engineer, in charge of production, Western Metal Specialty Co., 3043 North 30th Street, *Milwaukee.*

MCKENZIE, CHARLES SIDNEY (A) general superintendent, Ontario Steel Products Co., Ltd., *Gananoque, Ont., Canada;* (mail) P. O. Box 700.

MENZ, PETER G. (M) checker, Wright Aeronautical Corp., *Paterson, N. J.;* (mail) 300 Maryland Avenue.

MIANO, N. J. (A) eastern district manager, sales and service, Ralph N. Brodie Co., Inc., Oakland, Calif.; (mail) 2064 Ellis Avenue, *New York City.*

MONSELL, JOHN R. (J) junior mechanical engineer, United States Navy, aeronautical engine laboratory, Naval Aircraft Factory, Philadelphia; (mail) 57 East Center Street, *Woodbury, N. J.*

MURDEN, WILLIAM T. (M) research engineer, New Departure Mfg. Co., Bristol, Conn.; (mail) 376 Washington Street, *Forestville, Conn.*

PARKER, HARRY (A) assistant general manager, L. A. Young Industries of Canada, *Windsor, Ont., Canada;* (mail) 10025 McDougall Street.

PLATNER, JOHN B. (J) engineer, Chrysler Corp., Highland Park, *Detroit;* (mail) 308 Rowena Street.

RASMUSSEN, RICHARD E. (M) superintendent of shop, Chevrolet Motor Co. Experimental Laboratory, *Detroit;* (mail) 4337 Euclid Avenue, West.

RAWLINGS, EDWARD E. (M) manager, eastern section, manufacturers service division, Vacuum Oil Co., 61 Broadway, *New York City.*

ROSE, HAROLD L. (J) chief inspector, Kingston Products Corp., *Kokomo, Ind.;* (mail) 417 West Mulberry Street.

SMITH, EDWIN L. (J) full-size-body draftsman, Pierce-Arrow Motor Car Co., Buffalo; (mail) 24 Stella Avenue, *Kenmore, N. Y.*

THOMPSON, ROY E. (M) engineer, Lamb-Grays Harbor Co., *Hoquiam, Wash.;* (mail) 334 Karr Avenue.

TRINIDAD LEASEHOLDS, LTD. (Aff.) Pointe a Pierre, *Trinidad, British West Indies;* Representative: Johnston, H. C. W., general manager.

VOSHALL, LEROY BRODBECK (J) mechanical engineer, The Texas Co., Beacon, N. Y.; (mail) Box 351, *Fishkill, N. Y.*

WAITE, W. D. (A) manager, manufacturers sales, Dominion Rubber Co., Ltd., *Kitchener, Ont., Canada;* (mail) 20 Schneider Avenue.

YOUNGER, JOHN E. (M) professor of mechanical engineering, University of California, Mechanical Engineering Department, *Berkeley, Calif.*

ZIEGENBEIN, WALTER EMIL (A) vice-president, Borbein, Young & Co., *St. Louis;* (mail) 3745 Lindell Boulevard.

ZIMMERMANN, LUKAS (M) chassis designer, Chrysler Motor Corp., *Detroit;* (mail) 12120 Glenfield Avenue.

Notes and Reviews

AIRCRAFT

Principles of Flight. By Edward Archibald Stalker. Published by the Ronald Press Co., New York City, 1931; 428 pp., illustrated. [A-1]

This volume has been prepared essentially as a text-book for the engineering student who has completed a course in elementary aerodynamics and has acquired a fair conception of the physical principles on which the subject is based. Although the material does not proceed beyond a first course in calculus, a brief review of partial differentiation is included.

The following chapter titles give an idea of the scope of the book: The Nature of Air Forces; The Pitot and Venturi Tubes; Types of Flow; The Monoplane; Wing Combinations; Factors Affecting Fluid Forces; The Stream Function; The Velocity Potential; Flow Mechanics; Circulation, Impulse and Lift of Wings; Sources and Sinks; The Airscrew; The Prediction of Airplane Performance, Static Stability; Controls and Controllability; Dynamics; Dynamic Stability; and The Spinning of Airplanes.

Investigation of Damping Liquids for Aircraft Instruments—II. By M. R. Houseman and G. H. Keulegan. Report No. 398. Published by the National Advisory Committee for Aeronautics, City of Washington, 1931; 19 pp., with tables and charts. Price, 15 cents. [A-1]

Data are presented on the kinematic viscosity, in the temperature range —50 to +30 deg. cent., of pure liquids and of solutions of animal oils, vegetable oils, mineral oils, glycerine, and ethylene glycol in various low-freezing-point solvents. The thermal coefficient of kinematic viscosity as a function of the kinematic viscosity of the solutions of glycerine and ethylene glycol in alcohols is shown to be practically independent of the temperature and the chemical composition of the individual liquids. This is similarly true for the mineral-oil group and, for a limited temperature interval, for the pure animal and vegetable oils.

The efficiency of β-naphthol, hydroquinone and diphenylamine to inhibit the change of viscosity of poppy-seed and linseed oils was also investigated.

The Aerodynamic Characteristics of a Slotted Clark-Y Wing as Affected by the Auxiliary Airfoil Position. By Carl J. Wenzinger and Joseph A. Shortal. Report No. 400. Published by the National Advisory Committee for Aeronautics, City of Washington, 1931; 16 pp., with tables and charts. Price, 15 cents. [A-1]

Aerodynamic-force tests on a slotted Clark-Y wing were conducted in the vertical wind-tunnel to determine the best position for a given auxiliary airfoil with respect to the main wing. A systematic series of 100 changes in location of the auxiliary airfoil were made to cover all the probable useful ranges of slot gap, slot width and slot depth. The results of the investigation can be applied to the design of automatic or controlled slots on wings having geometric characteristics similar to those of the wing tested.

An increase of 41.5 per cent in the maximum lift above that of the plain wing was obtained for the slotted Clark-Y wing. At the same time, the angle of attack for maximum lift was increased 13 deg. It was found that a maximum increase of about 30 deg. was possible in the highest stalling angle, but at a maximum-lift coefficient slightly less than that of the plain wing. However, with one slot position, an increase of 25 deg., together with an increase in the maximum-lift coefficient of 23.3 per cent, was obtained. The best positions of the auxiliary airfoil were covered by the range of the tests, and the position for desired aerodynamic characteristics can easily be obtained from charts prepared especially for the purpose.

The Effect of Slots and Flaps on the Lift and Drag of the McDonnell Airplane as Determined in Flight. By Hartley A. Soulé. Technical Note No. 398; 12 pp., 17 tables and figs. [A-1]

Tests of N. A. C. A. Airfoils in the Variable-Density Wind-Tunnel. Series 44 and 64. By Eastman N. Jacobs and Robert M. Pinkerton. Technical Note No. 401; 31 pp., 11 figs. [A-1]

The foregoing two Technical Notes were issued during November and December, 1931, by the National Advisory Committee for Aeronautics, City of Washington.

Measurement of Visibility from the Pilot's Cockpit on Different Airplane Types. By Gerhard Kurz. Translated from *Zeitschrift für Flugtechnik und Motorluftschiffahrt;* Vol. 22, No. 6, March 28, 1931; Verlag von R. Oldenbourg, München und Berlin. Technical Memorandum No. 646; 17 pp., 29 figs. [A-1]

Spatial Buckling of Various Types of Airplane Strut Systems. By Alfred Teichmann. Translated from *Zeitschrift für Flugtechnik und Motorluftschiffahrt;* Vol. 22, No. 17, Sept. 14, 1931; Verlag von R. Oldenbourg, München und Berlin. Technical Memorandum No. 647; 8 pp. [A-1]

Measurements of Vertical Air Currents in the Atmosphere. By K. O. Lange. Translated from *Zeitschrift für Flugtechnik und Motorluftschiffahrt;* Vol. 22, No. 17, Sept. 14, 1931; Verlag von R. Oldenbourg, München und Berlin. Technical Memorandum No. 648; 9 pp., 11 figs. [A-1]

The foregoing three Technical Memoranda were issued during November, 1931, by the National Advisory Committee for Aeronautics, City of Washington.

Weight Estimate of Cantilever Monoplane Wings of Corrugated Aluminum-Alloy Box-Type Construction for Pursuit, Attack, Twin-Engined Observation and Transport Airplanes. Air Corps Technical Report No. 3496. Published by the Chief of the Air Corps, City of Washington; Oct. 30, 1931; 25 pp., with tables and figs. [A-1]

The object of this study was to determine, as closely as a rough design would permit, the unit weight at which metal wings of box construction could be built for pursuit, attack, twin-engined observation and transport airplanes.

The Economic Aspects of Transport-Plane Design. By A. A. Gassner. Published in *Aviation*, October, 1931, p. 583. [A-1]

The author names four requirements which must be fulfilled to make air transportation interesting to the general public: (*a*) speed must be appreciably higher than that offered by competitive ground transportation, (*b*) cost must be the same or only slightly higher, (*c*) reliability and dependability must be proved, and (*d*) a high degree of safety must be assured.

Of these, cost and speed have the most direct influence on the financial possibility of air transportation. Therefore, in his study, Mr. Gassner analyzes the factors that determine the transportation cost for present airplanes, together with the basic limitations for airplane-design characteristics and airplane operation.

The various expenses that make up the total operating cost are considered and methods of calculating costs are discussed.

(*Continued on next left-hand page*)

These items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G, Material; H. Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.

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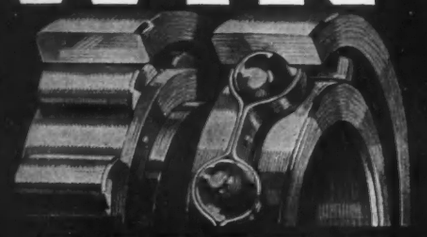
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Notes and Reviews

Continued

Zur Genauen Berechnung Vielholmig-Parallelstegiger, Ganz- und Halbfreitragender, Mittelbar und Unmittelbar Belasteter Flügelgeippe. By Eugen Sänger. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Oct. 28, 1931, p. 597. [A-1]

The requisite lightness of wing-truss structure can be attained, asserts the author, only when the material employed is utilized to the limit of its strength and the framework so formed that stresses are well distributed over the load-bearing members. The outer form of a wing is determined by aerodynamic considerations; within the limits so set the most suitable form of skeleton structure must be chosen.

For the purpose of load distribution over the entire wing structure, the author chooses the multispar type of framework, in which the ribs are set at right angles to the spars. He explains the way in which local stresses are equalized in this construction and emphasizes its superiority in this respect to the two-spar wing.

The main purpose of this article is to present a new and exact method of calculating the multispar, parallel web, full and semi-cantilever, directly and indirectly loaded wing-truss structure. With the aid of the mathematical analysis presented, which includes such factors as the loads encountered, the shifting in them due to varying angles of attack, the distance between spars, the effects of the fuselage joining and so forth, the dimensions of the structural parts can be more accurately predetermined, according to the author.

Baustoffragen bei der Konstruktion von Flugzeugen. By Paul Brenner. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Nov. 14, 1931, p. 637. [A-1]

Of what material will the aircraft of the future be built? Will the materials so far used be improved in the three essential characteristics of strength, uniformity and corrosion resistance, or will new materials be developed? Materials used affect not only the ability of the constructor to build an aircraft of lighest possible weight and at the same time of greatest strength and reliability; they influence design itself, asserts the author, who refers to the developments attendant on the introduction of duralumin in support of his statement.

In attempting to set the stage for answering the questions set forth, the author draws a picture of the present status of various aircraft materials, based on information concerning their more important properties and gives a few examples of the influence of materials on structural forms. He traces briefly the history of material development—the almost exclusive use, at first, of wood and fabric; the attention given to welded steel tubing and its present confinement to fuselage construction; the introduction and popularization of duralumin; and the struggle, emphasized in England, for the return to steel, this time with the use of high-strength, corrosion-resistant steel. Each of the materials mentioned and also magnesium are then discussed individually, their more important properties and the methods of joint-making being set forth and their respective merits compared.

Die DVL-Messnaben und ihre Verwendung beim Flugversuch. By Heinrich Ebert. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Oct. 28, 1931, p. 615. [A-1]

Test instruments designed to aid in the determination of the effect of altitude on aircraft-engine performance are described. The instruments were developed by the German institute for aeronautical research and have for their purpose the measurement, in flight, of propeller thrust and torque.

Each device consists of a measuring cylinder, circular in form, provided with a piston, which is installed between the propeller and the engine. The cylinder is stationary. Through an arrangement of thrust ball-bearings the propeller thrust or torque, whichever is being measured, is transmitted to the piston, which causes a proportional hydraulic pressure to be built up in the cylinder. This pressure can be read from an instrument dial in the cabin.

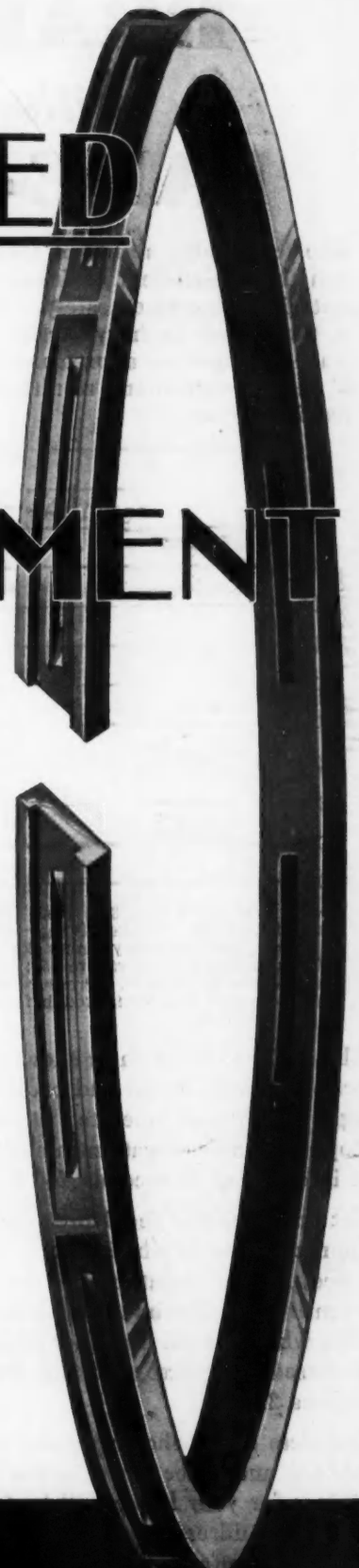
Trials are stated to have shown the instruments to be accurate within ± 1 per cent in the two sizes built, one for engines of 200 to 300 hp., the other for those of 400 to 600 hp. The weight is said to range from about 200 to 300 lb.

Pilot's Handbook, 1931. Written, compiled, edited and published by Pilot's Handbook Publishing Co., Los Angeles, 1931; 424 pp. and maps, illustrated. [A-3]

This book was prepared in an attempt to fill the need of the aviation industry for a composite handbook and reference guide.

(*Continued on next left-hand page*)

AN UNAPPROACHED RECORD OF ACCOMPLISHMENT



Never has any oil control piston ring as quickly accomplished so much in both performance and number of vehicle and engine manufacturers to whom it has sold itself as standard equipment.

Super Drainoil with its wear resisting bridges has been tested and proven to deliver full one hundred per cent oil control over A LONGER PERIOD than any other ring considered on

Brockway Truck	De Vaux	Hercules Motors
Buda Engine	Dodge Six	Hudson
Chrysler Six	Dodge Eight	Indiana Truck
Chrysler Eight	Dodge Truck	Nash Eight "70"
Chrysler Imperial	Durant Six	Plymouth
Chrysler Marine	Essex	Reo Eight "21"
Continental Motors	Federal Truck	Willys Six
De Soto Six	Gray Marine	Willys-Knight "66-D"
De Soto Eight	Hall-Scott Motors	Willys-Knight "95"

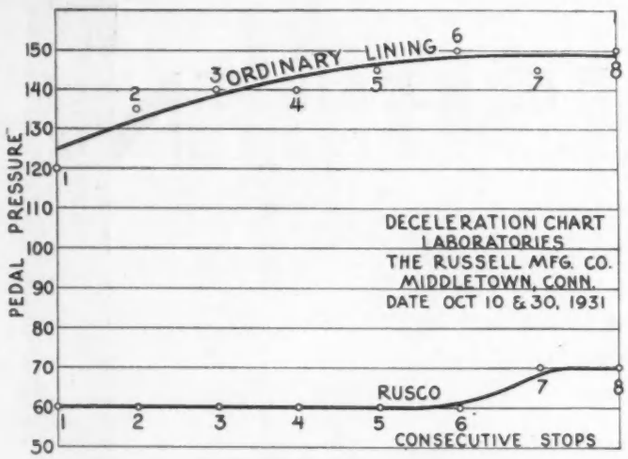
These cars are now equipped with Super Drainoil "Sealed Power" installations.

THE PISTON RING CO.
MUSKEGON, MICHIGAN

Super DRAINOIL

BRAKES *without* FADE-OUT

The remarkable ability of Rusco Brake Linings to retain their co-efficient of friction at high temperatures materially increases safety. Continuous application of the brakes in heavy traffic or on steep mountain grades requires no appreciable increase in the amount of pedal pressure and results in practically no loss in braking power.



Data: Weight of car, 3065 lbs. Drum size, 11.500. Drum material, steel. Brake lining mileage at time of test (Rusco), 1486; ordinary lining 2851. Tire size, 4.75 x 19. Weather, clear; temperature 65°; road, cement—both tests. Decelerometer, Bendix. Pressure Gauge, Bendix. Brakes fully adjusted and equalized before both tests. Name of car on request.

The accompanying chart shows the comparative pedal pressures with Rusco and ordinary brake lining on a light weight car, operated at 45 miles an hour, and stopped at a deceleration rate of 15 ft. per sec. per sec. at intervals of 45 seconds, for 8 consecutive stops.

Not only was the pedal pressure required with Rusco approximately one-half of that with the other lining tested, but no variation was registered until after the seventh stop. Maximum variation with Rusco was only 12% whereas with the other lining, the pedal pressure increased after first stop and the variation ranged as high as 21%.

Complete charts showing pedal pressure, deceleration, fade-out and other performance data on Rusco Brake Linings for your brake will be furnished gladly upon request. Address Engineering Department, B-76, The Russell Manufacturing Company, Middletown, Conn.

RUSCO BRAKE LININGS

Notes and Reviews

Continued

particularly for the use of pilots and those on the ground who are responsible for the construction of aircraft and the organization and operation of airlines.

The Handbook contains a complete text of the Weems System of Aerial Navigation, personally prepared by Lieut.-Com. P. V. H. Weems. Complementary to this navigation text is a section compiled for use by fliers who have not had the benefit of studying navigation and therefore are in need of precise navigation data in the form of plotted courses.

The book also includes 21 sectional Mercator flying maps of the United States; a contribution on Blind Flying and Radio-Bearing Flying, by Lieut. A. F. Hegenberger; a treatise on Meteorology, included through the courtesy of Thomas R. Reed, of the United States Meteorological Service; and, for the use of the airport manager, a compilation of Department of Commerce regulations, a table of airports and emergency landing-fields and, for the industry, a Buyer's Guide, as well as an article on Airport Construction and Management, contributed by Dr. Austin F. MacDonald, of the University of California.

Jahrbuch 1931 der Deutschen Versuchsanstalt für Luftfahrt, E. V. Berlin-Adlershof. Edited by Wilhelm Hoff. Published by R. Oldenbourg, München, 1931; 816 pp., 1640 illustrations. [A-3]

The Year Book of the DVL (German Experimental Institute for Aviation) contains a report about general activities for 1930-1931 and 260 summaries of investigations; about 58 of them are republished in full. About half of the last-mentioned reports are published here for the first time, which means a departure from early practice. As an aid for readers interested only in definite questions of the DVL work, the different parts of the Year Book are obtainable as separate booklets; so one may have single reports of the research departments for aerodynamics, statics, engines, materials, aerial photography and navigation, electrotechnics and wireless, and flying.

The testing department type-tested 65 new airplanes, made 131 subsequent airplane tests, and 748 periodical inspections were carried out. A few of the more important subjects covered by the papers which have been published by the research departments of the Institute may be cited.

Within the scope of the aerodynamic investigations are model tests on artificial ventilation of engine-test benches and trial rides with a propeller-driven speed car. The department for statics published several reports on structural requirements and the results of tests with aircraft parts; two investigations relate to calculations of space framework. The papers of the engine department include mechanical properties of the parts of spark-ignition aeronautic engines under different service conditions, trials with a supercharger, possibilities of the waste-gas-jet propulsion, torsional oscillations of in-line engines and studies of engine knocking.

Two very thorough investigations of the material department relate, on the one hand, to the welding properties of steel parts for aircraft, and, on the other hand, to static and dynamic strength of different light metal alloys. Other papers deal with corrosion tests of sheet material and cables, trials with finishing materials and engine tests with regard to fuel research. The department for aerial photography and navigation publishes, among others, a paper about the checking of lenses with regard to distortion, and two others about increasing the sensitivity of photographic emulsions.

From the papers of the electro and wireless department two new investigations may be cited. One relates to the influence of the position of the sun upon wireless waves and the other to auto-direction-finding by radio. The reports of the flight department deal with the effect of Handley Page slotted ailerons, the influence of the slipstream upon the rudder, and determination of the effect of wing contours and aileron size upon the lateral maneuverability of monoplanes.

Air Navigation. By P. V. H. Weems. Published by the McGraw-Hill Book Co., Inc., New York City and London, 1931; 589 pp., illustrated. [A-4]

The author points out that in the earlier stages of aviation the aviator's efforts were almost completely absorbed in the problem of taking off and keeping his plane in the air. Increased knowledge of aerodynamics, improvements in materials of construction, and the development of the air-cooled engine have done much to simplify this problem.

In the future the mechanics of flying will require less and less of the aviator's attention and he will be able to direct his efforts

(*Continued on next left-hand page*)

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...more than 200 engineers have accepted

In the intricate and highly specialized science of steering, Ross feels that it occupies a foremost position—both from standpoint of experience and of achievement. Our accumulation of steering knowledge—the results of our research and work with every type of steering installation—is freely offered to the automotive industry. Of the engineering staffs which have availed themselves of this service, more than 200 have specified Ross Cam and Lever Steering as standard equipment.

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Propeller Shafts

for
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PARISH FRAMES PARISH PRESSED STEEL CO., READING, PA.

Notes and Reviews

Continued

more and more toward finding his way in the air and overcoming such obstacles as blind flying and wind.

In addition to the commonly used methods of piloting and dead reckoning, this book, the author states, is intended to emphasize the importance of position finding by means of celestial observations and by radio bearings. Only the simplest and fastest methods of taking such observations are given, since practical work in the air has shown how impracticable it is to use any but the shortest and simplest methods for air work.

In concluding, Lieutenant-Commander Weems declares that only a scratch has been made on the surface of the art of celestial navigation in the air; he calls attention to the fact that there is available at the present time no entirely satisfactory sextant, no "air almanac," nor many handy tables and simple devices needed in aerial navigation.

Ground Lighting Equipment. Prepared by the British National Aviation Lighting Sub-Committee. Published in *Aircraft Engineering*, October, 1931, p. 255. **[A-4]**

In compliance with the recommendations of the International Commission on Illumination, made at the meeting in Saranac, 1928, a British committee was formed in June 1929, representing all the interests connected with civil aviation, including the Air Ministry, the operating companies and the manufacturers of aviation equipment.

In this paper the committee summarizes the data discussed at its numerous meetings and presents the fundamental considerations and detailed design of lights for airway and airdrome use.

Transmission of Light Through Fog. By F. C. Breckenridge. Published in *Aircraft Engineering*, October, 1931, p. 261. **[A-4]**

During the last 12 years six investigations of the spectral transmission of light through fog, mist or haze have been made in the near future to undertake a similar discussion of fog varied. Three of the researches were made with fog chambers and three with natural fogs. Varied path widths, fog densities and spectrum ranges were covered in these six studies. Therefore it is not surprising that curves based on data taken under such diverse conditions should show little resemblance to one another.

In this article, the author attempts to correlate the results of these investigations and expresses the hope that he will be able in the United States. The conditions of the tests have been researches conducted in foreign countries.

Anti-Aircraft Gun Control. By Roswell H. Ward. Published in *Army Ordnance*, September-October, 1931, p. 115. **[A-4]**

This is the third and concluding article in a series describing the Sperry anti-aircraft gun-control system, together with a brief introductory outline of the problem of defense against air raids.

Methods by which the essentials of anti-aircraft gun control are met by the Sperry system are outlined in a description reviewing the component parts of the gun-control unit, offering a few typical examples of the methods of mechanical computation employed, and presenting a step-by-step outline of the way in which these mechanisms work together to automatically compute the gun angles and fuse settings required.

The first two articles of the series appeared in the May-June and July-August, 1931, issues of *Army Ordnance*.

The Development of Aircraft Manufacture. By Glenn L. Martin. Published in *The Journal of the Royal Aeronautical Society*, October, 1931, p. 894. **[A-5]**

This paper constitutes a comprehensive survey of the development of production methods in the aircraft industry. The underlying factors to be considered in manufacturing and the problems peculiar to this comparatively new production product are discussed at length, with numerous references to and illustrations from Mr. Martin's own plant.

EDUCATION

The Training of Young Automobile Engineers. By B. G. Robbins. Paper presented before the Institution of Automobile Engineers, London, England, Nov. 3, 1931. **[D-3]**

In response to a request from the Institution of Automobile Engineers, the author prepared this review of education as related to the automobile industry, in which he discusses: (*a*) an outline of present-day conditions, covering the existing types of training available and the subsequent prospects offered by the industry, and (*b*) some of the major features of the training schemes

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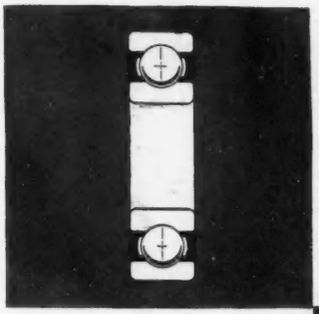
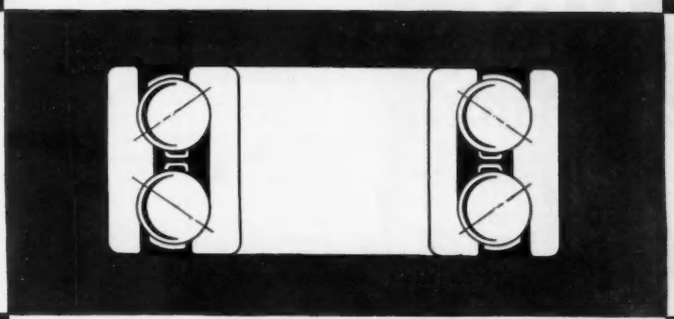
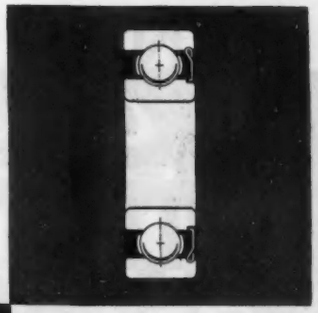
NEW DEPARTURE BALL BEARINGS

for cars, trucks and busses.

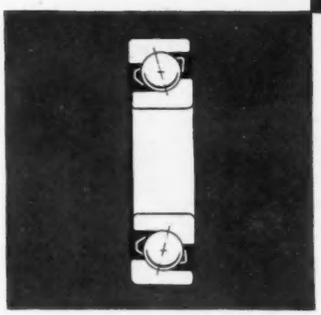


SINGLE ROW: Essentially a carrier of radial loads, yet capable, too, of resisting a certain amount of thrust. It is built in two types, with and without filling notches.



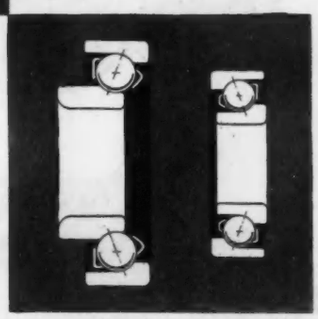


SHIELDED: A single row bearing fitted with a permanent metal shield, which serves to keep dirt and other foreign matter away from the rolling elements.

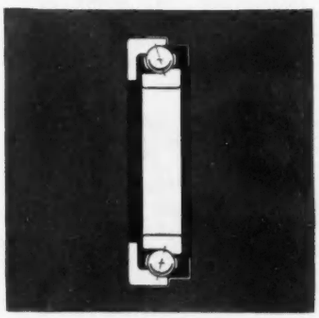


RADAX TYPE O: An angular contact bearing with equal capacities for radial and one direction thrust loads. Generally used in pairs, especially for differential support.

THE DOUBLE ROW: There is one position in a car which, above all others, demands a bearing of unquestioned merit. The pinion. New Departure has extended every effort in the design and production of a bearing capable of handling the job with a minimum of attention. Study the design of the double row shown above. Race rings are solid forgings. There are as many large balls as a balanced design will permit. Contact angles are such as to promote great rigidity. And the bearing is assembled under slight compression to enchance that rigidity, and resist deflection. Radial and thrust loads from either direction are safely carried by this unit. It never requires adjustments.



FRONT WHEEL: Used in pairs for front wheel support. Packed with grease, properly adjusted they demand little attention during the life of the car they serve. Free rolling promotes free wheeling.

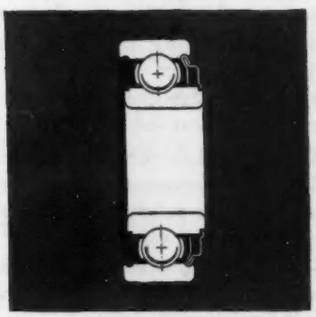


CLUTCH THROWOUT: In some instances, free wheeling increases the duty of the throwout bearing. Here, as elsewhere, continuous good performance is assured through the use of a New Departure.

Specify

New Departure Ball Bearings

Your use of anti-friction bearings can be highly successful if you will permit New Departure engineers to assist you. The New Departure Mfg. Company, Bristol, Conn.



N-D-SEAL: Where a bearing must run for years without attention of any sort, the N-D-Seal best meets the situation. Grease-packed and felt-sealed to keep out dirt, it is a long stride forward in small bearing design.

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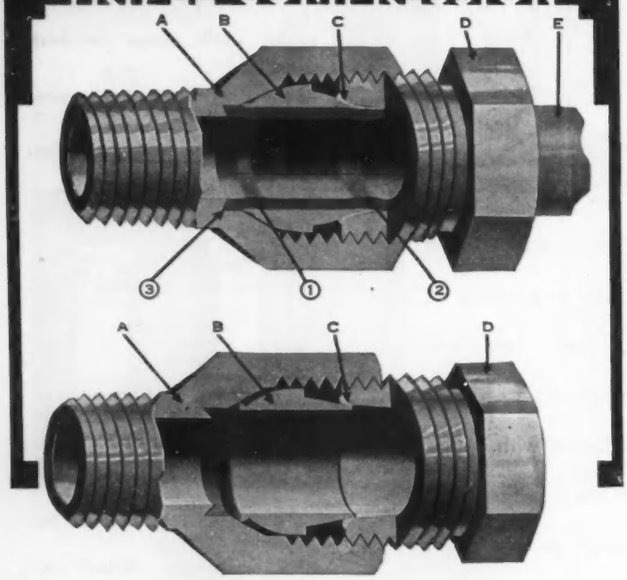
UNIVERSAL ALL-TUBE COUPLING

TRIPLE COMPRESSION



WITHOUT TUBING – BEFORE COMPRESSION

(1) First Compression
(2) Second Compression
(3) Third Compression
Patented February 3, 1931 No. 1,791,121

(A) Body
(B) Sleeve
(C) Solder Bearing
(D) Nut
(E) Seamed Tubing

Approved by the Underwriters Laboratories

HERE is the result of supreme engineering effort and experience to provide a single type of compression coupling to fit universally all seamed or seamless tubing of steel, aluminum, brass or copper. It is no longer necessary to depend upon couplings of various designs and construction for joining differently constructed kinds of tubing.

This Dole Universal All-Tube Coupling of two piece design surpasses all for joining to seamed or seamless tubing—for safety against leakage—for holding under all strain and vibration—for simplicity of connection—no separate sleeves—no flaring—no soldering—for reconnecting speedily and without limit—*for ultimate satisfaction and economy.*

The coupling consists of only the body and the threaded sleeve screw. Repeated connecting will not reduce the efficiency. Finger turned except for the compression turn. The solder which holds the sleeve on to the nut is sheared off during compression, thus giving a lead lubricated bearing—an exclusive Dole feature.

Our engineering department will be pleased to work with you in the application of Dole Universal All-Tube Couplings. Cut open samples will be sent free upon request.

THE DOLE VALVE COMPANY
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Notes and Reviews

Continued

which have often been the subject of controversy and which still demand solution or modification in the light of present conditions.

ENGINES

Hydraulics of Fuel-Injection Pumps for Compression-Ignition Engines. By A. M. Rothrock. Report No. 396. Published by the National Advisory Committee for Aeronautics, City of Washington, 1931; 48 pp., with tables and charts. Price, 25 cents. **[E-1]**

Formulas are derived for computing the instantaneous pressures delivered by a fuel-pump. The first derivation considers the compressibility of the fuel, and the second, the compressibility, elasticity and inertia of the fuel. The second derivation follows that given by Sass and is shown to be the more accurate of the two. Additional formulas are given for determining the resistance losses in the injection tube. Experimental data are presented in support of the analyses. The report is concluded with an application of the theory to the design of fuel-pump injection systems for which sample calculations are included.

Performance of a Compression-Ignition Engine with a Precombustion Chamber Having High-Velocity Air Flow. By J. A. Spanogle and C. S. Moore. Technical Note No. 396; 15 pp., 15 figs. **[E-1]**

Some Characteristics of Fuel Sprays at Low Injection Pressures. By A. M. Rothrock and C. D. Waldron. Technical Note No. 399; 6 pp., 9 figs. **[E-1]**

The foregoing two Technical Notes were issued during October and November, 1931, by the National Advisory Committee for Aeronautics, City of Washington.

The Internal-Combustion Engine and Its Performance. By W. A. Tookey. Published in *The Automobile Engineer*, October, 1931, p. 416. **[E-1]**

Mr. Tookey is president of the Institution of Automobile Engineers, and as stated in this article, is conversant with the various stages of development of the internal-combustion engine since the early '90's. In his presidential address he undertakes to correlate the performances of present-day types for stationary, marine, air, and land-transport purposes, pointing out that, while the creations of the automobile engineer are fully realized, through experience, by their colleagues in the heavy-duty field, the accomplishments of the latter group are not so well known to the automobile engineer.

Exhaust-Gas Analysis. By C. B. Dicksee. Published in *The Automobile Engineer*, October, 1931, p. 401. **[E-1]**

The Orsat flue-gas-analysis apparatus, which has been in such universal use in the boiler house for many years, has received very little attention from the automobile engineer. The author contends that it will yield more information than almost any other single piece of apparatus that is available to the worker on internal-combustion engines. He describes the Orsat equipment and sets forth its application to such engines, including two-stroke-cycle and compression-ignition engines.

Sur l'Allumage et la Combustion dans les Moteurs Rapides. By A. Grebel. Published in *Journal de la Société des Ingénieurs de l'Automobile*, October, 1931, p. 1482. **[E-1]**

To what extent do the conventional theories of Otto and Diesel-cycle operation coincide with the actual course of ignition and combustion in present high-speed high-compression engines of both types? If discrepancies exist, what light do they throw on certain anomalies that defeat a thorough understanding of combustion processes and how may engineers, through a clearer vision of the occurrences inside the cylinder, reach their goal; more power delivered at the crankshaft in proportion to the calories consumed in the combustion chamber?

In seeking the answer to these questions in the present article, the author urges that engineers interest themselves not only in questions of mechanics but also in chemical and physical manifestations. He warns against engine tests of fuels, lest to the fuels tested be attributed faults of the engine. He discusses the possibilities of increasing thermal efficiency and power by an increase of pressure and speed. Examining the question of Diesel operation, he questions the reliability of ignition by compression and concludes that, to obtain flexibility and high speed in an engine of this type, the variations in the speed of ignition and combustion must be compensated for by a complete regulation of injection. He contends that the theoretical cycles are not realized

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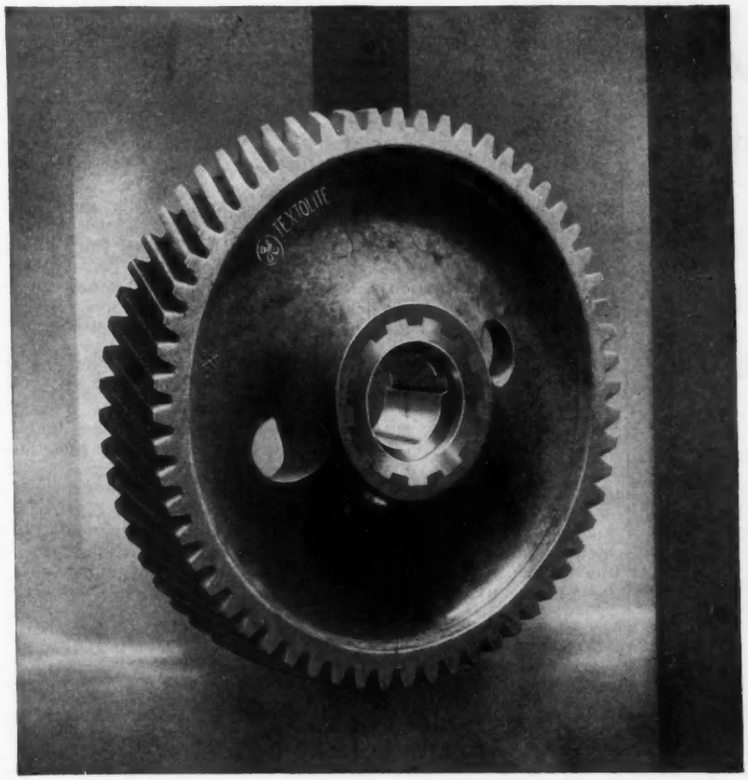

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Precise Timing for 50,000 Miles

TEXTOLITE TIMING GEARS

A GOOD nonmetallic gear—made of a material only half as dense as aluminum—has the lowest possible effective mass and is subject to the lowest acceleration and deceleration stresses.

A good nonmetallic gear is nearly 40 times as resilient as a steel gear. This resilience greatly prolongs the life of the drive.

A good nonmetallic gear is soft and nonresonant and eliminates all metal-to-metal clashing.

A good nonmetallic gear wears less than 0.001 in. in 20,000 miles. Displacement between camshaft and crankshaft is negligible. The initially perfect timing is maintained for 50,000, often 100,000, miles.

A good nonmetallic-gear timing drive betokens conscientious, uncompromising manufacture throughout the car.

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SALES AND ENGINEERING SERVICE IN PRINCIPAL CITIES

Specializing in meeting *your particular requirements*

The men responsible for the control of the operations of manufacture in the Bethlehem Alloy Steel Plant are specialists in the art of making steel that is just suited to the customer's requirements in every particular, both as to the properties that make for long life in the intended service and those that facilitate working in the shop.

The thorough understanding of the problems of alloy steel users which makes this close cooperation possible is the result of many years of experience in manufacturing alloy steels for every industry using these materials. Bethlehem Metallurgists have always worked with customers in solving the problems arising in the application of alloy steels to their uses. In this way a great fund of information pertaining to the handling of alloy steels so as to obtain the highest possible degree of satisfaction has been obtained, and is available to help in solving your alloy steel problems.

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BETHLEHEM ALLOY STEELS

Notes and Reviews

Continued

in present practice and that combustion does not occur at constant volume in so-called constant-volume engines nor at constant pressure in constant-pressure engines.

Other topics discussed are the necessity of better combustion-chamber design; the shape and physical content of fuel sprays in injection engines; the mechanism of detonation and the action of detonation suppressers. He questions both the pressure-wave and peroxide-formation theory of detonation, and offers an explanation based on physical phenomena, and deplores, for reasons of health, the use of organic-metal knock suppressers.

Diesel Reference Guide. By Julius Rosbloom. Published by Industrial Institute, Inc., Jersey City, N. J., 1931; 292 pp., index and directory. **[E-3]**

This volume is termed a book for reference purposes and instruction on modern Diesel engineering for land, marine, locomotive, aero-service, automotive and portable duties. In the first section is given in easily understandable language the general theory of the Diesel engine, its principles of construction and operation and problems connected with the various types mentioned above. The second section contains a directory of the world's leading manufacturers of Diesel engines and manufacturers of auxiliaries, accessories and other Diesel-engineering products.

The High-Speed Internal-Combustion Engine. By Harry R. Ricardo. Published by D. Van Nostrand Co., Inc., New York City; revised edition 1931, 435 pp., illustrated. **[E-3]**

The present volume is a revised and somewhat extended edition of Vol. II of The Internal-Combustion Engine, published in 1923.

The author points out that, although considerable progress has been made during the seven years that have elapsed since the previous volume was published, it has, for the most part, taken the form of improving and consolidating existing orthodox design, the only important new development during this period being the achievement of the high-speed Diesel.

Since progress has, to a large extent, followed along the lines foreshadowed in the original volume, which dealt mainly with general principles rather than specific designs, only a limited amount of revision has been required. However, there are a number of additions, notably a new chapter dealing with the high-speed Diesel engine.

HIGHWAYS

A Traffic-Control Plan for Kansas City. By The Albert Russel Erskine Bureau, Harvard University. Survey sponsored and report published by the Chamber of Commerce of Kansas City, Mo., 1930; 251 pp. **[F-4]**

Early in 1929, with Kansas City's street-traffic problem approaching an acute stage, the Chamber of Commerce assumed the responsibility for unifying efforts to improve conditions. The City-Wide Traffic Committee, composed of 40 representatives of official departments and civic and business groups most closely concerned with the problems of traffic, was organized. This committee engaged the services of the Albert Russel Erskine Bureau, of which Dr. Miller McClintock is director, to make a comprehensive survey and report.

A fund of more than $30,000 was raised to finance the survey, and Dr. McClintock, with the aid of a corps of engineers, spent more than a year in the preparation of the report. On the basis of the facts collected, recommendations have been made for a complete reorganization and adjustment of the methods of traffic control in the city.

The report shows how the standards and recommendations developed by the National Conference on Street and Highway Safety can be adapted for use in a city with average traffic problems. It has been prepared with a view not only of developing a constructive plan of traffic control for Kansas City but also of presenting principles of traffic relief that are valuable in any city in which problems of street congestion and traffic accidents exist.

MATERIAL

Advantages of Oxide Films as Bases for Aluminum-Pigmented Surface Coatings for Aluminum Alloys. By R. W. Buzzard and W. H. Mutchler. Technical Note No. 400. Published by the National Advisory Committee for Aeronautics, City of Washington, November, 1931; 16 pp., 13 figs. **[G-1]**

The problem of producing a satisfactory alloy that is corrosion resistant under severe conditions and has the requisite

(Continued on next left-hand page)

AC now offers the REMO Injector and REMO Gum-Solvent Fluid to permit new development with higher compression engines . . .

REMO keeps the engine free from carbon . . . . ends valve sticking — prevents binding and clogging of piston rings

Carbon troubles — the pre-ignition and loss of power which result when carbon accumulates in the combustion chambers of high-compression engines — need no longer stand in the way of their development. Valve sticking and other "gum" troubles, too, can be overcome — by equipping with a Remo Injector. This new engineering achievement makes it easy and inexpensive to keep an engine free from gums and carbon. It introduces an entirely new fluid, an effective solvent for the gums, formed during the combustion of gasolines and lubricating oils, which bind together the carbon deposits. It has been tested thoroughly under actual service conditions — it has demonstrated its ability to keep an engine *clean* throughout its life. An injection of Remo every 1,000 miles removes the gum from valve stems — loosens carbon and road dust accumulations from cylinder heads and pistons — frees top piston rings — and keeps the slots in oil rings clear. By keeping the engine free of deposits, it prevents overheating and loss of volumetric efficiency. It can do no harm. An AC representative will gladly bring you complete information about this new accessory that opens the door to further progress with high engine compression.

AC SPARK PLUG COMPANY, FLINT, MICHIGAN

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Notes and Reviews
Concluded

physical properties of light weight and high strength has not yet been completely solved. The alternative is to use the alloys now known to have the best physical properties and to obtain improved corrosion resistance by the application, either chemically or mechanically, of protective coatings or films which will tend to retard corrosion. The investigation of this problem was conducted at the Bureau of Standards in cooperation with the National Advisory Committee for Aeronautics, the Bureau of Aeronautics of the Navy Department and the Army Air Corps.

The purpose in this paper is to present the results obtained in a number of corrosion tests, made by various methods on a combination oxide-varnish coating which was found to possess a degree of corrosion resistance superior to that of a number of other coatings investigated. The tests reported represent only a relatively small number of those performed in connection with a current research, begun in 1925, that is being conducted at the Bureau of Standards on the corrosion of light metal alloys used in aircraft.

Dividends from the Institute's Fundamental Research. By J. Bennett Hill. Paper presented before the 12th annual meeting of the American Petroleum Institute, at Chicago, Nov. 10 to 12, 1931. **[G-1]**

The author predicts that the refining industry will not be satisfied in the future with the manufacturing of fuels and lubricants but will produce by synthetic methods such materials as soaps, rubber, drugs, textiles and possibly even foods. He likens the fundamental research leading toward these potential products of the petroleum industry to the clearing of a field preparatory to raising a crop of wheat, and evaluates the work that has been done toward that end by the American Petroleum Institute with the financial aid of John D. Rockefeller and the Universal Oil Products Co.

Dr. Hill reviews the status of the projects which comprise this research and in conclusion urges that the work be continued on the unfinished projects of the five-year program.

Troubles! By J. A. C. Warner. Paper presented before the 12th annual meeting of the American Petroleum Institute, at Chicago, Nov. 10 to 12, 1931. **[G-1]**

In this article the author reviews briefly the outstanding and practical results obtained during the last 10 years through the cooperative efforts of petroleum and automotive technologists and executives working in sympathetic association. The medium for this relationship, the Cooperative Fuel-Research Steering Committee, is a joint committee representing the American Petroleum Institute, the National Automobile Chamber of Commerce, the Society of Automotive Engineers and the United States Bureau of Standards.

In conclusion, Mr. Warner urges that the cooperation be continued and the work pushed forward, since only through such cooperative effort can continued and even greater consumer satisfaction be realized.

MISCELLANEOUS

Einiges aus der Mechanischen Oberflächenbehandlung im Automobilbau. By Guido Prachtl. Published in *Automobiltechnische Zeitschrift*, Sept. 30, p. 610; Oct. 10, p. 634; Oct. 20, p. 663; and Nov. 10, 1931, p. 711. **[H-5]**

In this series of articles on the surface treatment of parts in automobile production the author deals with two types of process: case hardening and the mechanical finishing of metals.

Much attention is given to nitriding, the effects of temperature, time of immersion and type of metal being processed. Internal stresses in the parts to be treated must be avoided, points out the author. He selects two of the series of steels developed by Krupp for nitriding purposes and gives their chemical composition and physical properties. To illustrate the nitriding process, its application to a bevel gear is followed through, information being given on the metal used, the heat treatment, the time and control of the nitriding, and the cost involved as compared with other processes.

A second case-hardening method similarly dealt with is the double-Duro process, developed by the Bergische Stahlindustrie, a subsidiary of the Deutsche Edelstahlwerke. Simplicity and ease of operation are claimed as advantages of this process. It was originally developed for hardening the bearing surfaces of crankshafts and its use for this purpose is described in some detail.

In the second division of the series the author describes the application of various mechanical finishing processes to internal bores, grooves, cylinders and gears.

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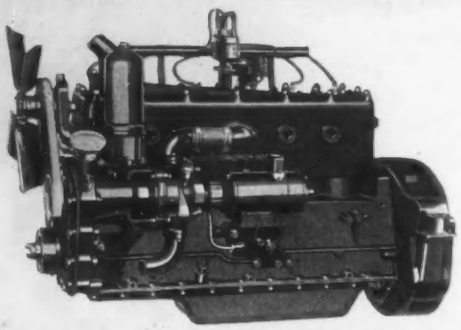

The Continental Red Seal Engine Series E-600

SPECIFICATIONS

	Bore	Stroke	Displacement	H. P.
E-600	3 11/16	4 1/2	288	73
E-601	3 7/8	4 1/2	318	80
E-602	4 1/8	4 1/2	360	90
E-603	4 1/4	4 1/2	382	98

The Continental E-600 six cylinder series for trucks offers unusual efficiency and economy of operation in a closely graduated power range. These engines, having the same installation dimensions, are interchangeable in engine mountings. Special "dry-gas" manifolding and cylinder head design provide unusual horsepower per pound of weight and per cubic inch of displacement. Cooling system provides ample flow of water around all cylinder barrels and around valves. Exhaust valve ports are completely jacketed. Gear driven pressure feed oil system to all wearing parts assures long life.

Provision is made for mounting every type of accessory individually or in combination—distributor, magneto, air cleaner, thermostat, oil filter, air compressor, 750-watt generator, velocity type governor.

At all speeds, unusually high power output is coupled with economical operation.

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Personal Notes of the Members

(*Continued from p.* 35)

out plans which he had made earlier in the year previous to the appointment of Roy H. Faulkner to the post.

Mr. Cord is president also of the Cord Corp., of which the Auburn company is one of the 11 divisions.

Harold Adams Backus has joined Pitcairn Aircraft, Inc., of Willow Grove, Pa., in the capacity of experimental engineer. He was formerly superintendent of the Metallurgical Laboratories, Inc., of Philadelphia.

Petrus A. Carlson has entered the employment of the Consolidated Aircraft Corp., of Buffalo, N. Y., as a draftsman and designer.

John Chucan, formerly resident in Chicago, is now working in Leningrad, U. S. S. R., as efficiency engineer with the Kr. Putilow, which is manufacturing tractors.

E. P. Clarkson, who latterly has been managing director of the Canadian Austin Car Co., in Toronto, and before that was in charge of Dodge Bros. interests in Canada, recently established the firm of E. Palmer Clarkson & Associates, of Toronto, managing engineers and market analysts. The new firm will specialize in providing manufacturers in the United States with surveys and analyses of manufacturing and commercial possibilities in the Dominion and the British Empire at large.

L. M. DeTurk has been advanced by the J. G. Brill Co., of Philadelphia, from the position of designing engineer in the autocar division to that of experimental engineer of the company.

Having given up his position as a layout draftsman with the Reo Motor Car Co., of Lansing, Mich., **Ralph J. Duckworth** has entered the service of the Buick Motor Co., of Flint, Mich.

F. O. Freeman has been elected president of the Old Guard Securities Corp., of New York City, a holding company for lubricants manufacturing companies. He was formerly a director of Air Investors, Inc., of the same city.

Louis A. Gilmer has assumed new duties as designing engineer on Diesel engines with I. P. Morris & De La Vergne, Inc., of Philadelphia. His former connection was with the International Engineering Corp., of Chicago, as mechanical engineer.

Hall L. Hibbard, who was project engineer of the Stearman Aircraft Co., of Wichita, Kan., has assumed new duties as supervising engineer with Stearman-Varney, Inc., of Alameda, Calif.

Elmer P. Jasper has been appointed chief engineer and plant superintendent of Lodge Motors, Inc., of Detroit. His previous position was that of chief engineer of the motor division of the Chris Craft Corp., of Algona, Mich.

J. T. Lansing, who used to be manager of the sales-promotion department of the United American Bosch Corp., of Long Island City, N. Y., is now working in the engineering department of the Scintilla Magneto Co., Inc., in Sidney, N. Y.

William Lind, who has been assistant sales manager of General Motors, G.m.b.H., in Berlin, Germany, has notified the Society that his address now is General Motors Export Co., New York City.

George H. McCauley, formerly an engineer with the American Oil Co., of Baltimore, is now associated with the Brockway Motor Truck Corp., and is located in Baltimore.

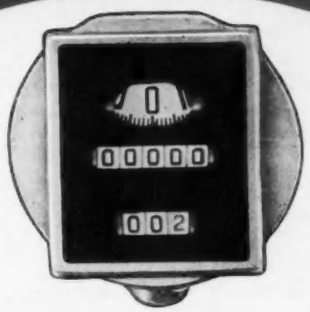
W. S. Pritchard, formerly factory manager of the Detroit Aircraft Corp., is now connected with the Doehler Die Casting Co., of Toledo, Ohio, in the capacity of development engineer.

Arthur B. Schultz has been engaged by the Oakland Motor Car Co., of Pontiac, Mich., as a tool designer.

(*Concluded on next left-hand page*)

NORTH EAST

S·P·E·E·D·O·M·E·T·E·R·S



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Personal Notes of the Members
Concluded

David T. Sicklesteel has rejoined the Detroit Gear & Machine Co., of Detroit, in the capacity of experimental and development engineer. His previous connection was with the engineering staff of the Muncie Products Division of the General Motors Corp., in Muncie, Ind.

Harry G. Smith has assumed new duties as designer with the Buick Motor Co., of Flint, Mich. His previous connection was with the Studebaker Corp., of South Bend, Ind., as chassis engineer.

Lloyd Stearman has been elected president, director and general manager of Stearman-Varney, Inc., of Alameda, Calif. He was formerly president and a director of the Stearman Aircraft Co., of Wichita, Kan.

Julius Steindler, formerly director and manager of Denes & Friedmann, A. G., of Vienna, Austria, has joined as a partner in the firm of Steindler & Gaiger, which is manufacturing automotive products in the same city.

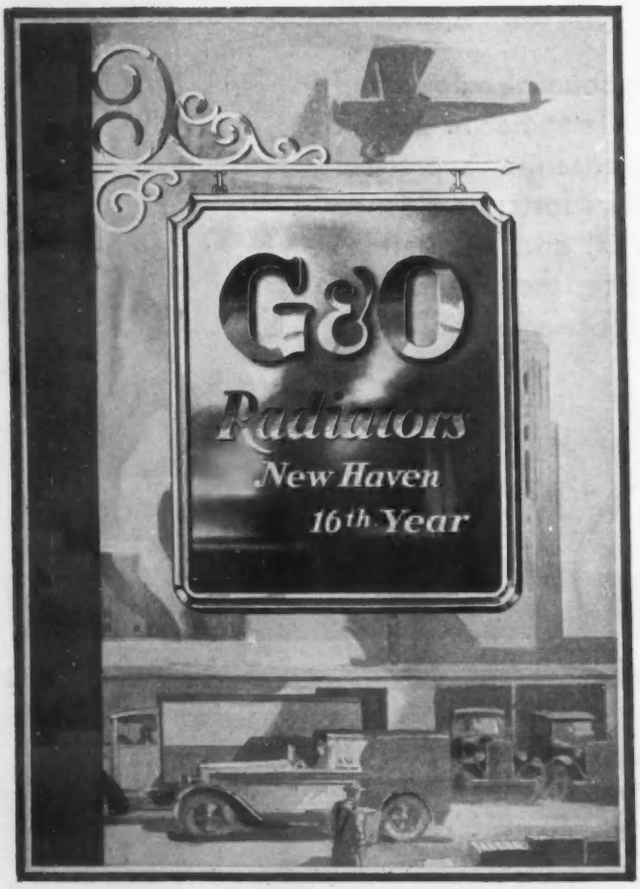
Herman Stoll, formerly chief draftsman for Adam Opel, A. G., of Russelheim, Germany, has returned to this Country and is now doing research work in the engineering department of the Chevrolet Motor Co., of Detroit.

William Vollheim, who used to be a draftsman for Fairbanks, Morse & Co., of Beloit, Wis., is now in the employment of the Curtis-Wright Airplane Corp., of Paterson, N. J.

Oscar Werner is now connected with the William Gent Mfg. Co., of Cleveland, as development engineer.

Henry J. White, having resigned as pilot, secretary and treasurer of the James C. Willson Flying Corp., of New York City, has joined the Vacuum Oil Co., also of New York City, as general aviation representative for Europe.

E. G. Williams, who used to be export counsel for the Franklin Automobile Co., of Syracuse, N. Y., is now a representative for the Chrysler Export Corp., of Detroit.



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If you have moved please notify the office of the Society so that you will not miss an issue of your Journal.

S. A. E. Journal

JANUARY, 1932

REPORTS OF DIVISIONS TO STANDARDS COMMITTEE

Standards Committee Meeting
Monday, Jan. 25, 1932
at 10 o'clock
Crystal Ballroom, Book-Cadillac Hotel
Detroit

THE SOCIETY OF AUTOMOTIVE ENGINEERS, INC.
29 WEST THIRTY-NINTH STREET
NEW YORK CITY

Reports of Divisions to Standards Committee

Standards Committee Meeting Jan. 25, 1932

Crystal Ball Room—Book-Cadillac Hotel—Detroit

IN this pamphlet are printed the reports that have been prepared for submission to the Standards Committee and to the Society by 10 Divisions of the Standards Committee since the Semi-Annual Meeting last June.

All of the reports are submitted at this time for approval after having been considered carefully by the respective Divisions and given as wide publicity as possible by publication in the S.A.E. JOURNAL from month to month. The reports, as now presented, are believed to be in acceptable form, and any proposals should be only in the nature of important and carefully considered constructive changes.

Under the Standards Committee Regulations, these reports may be approved as presented, amended within limitations or referred back to the respective Divisions for sufficient reason. The action taken on them by the Standards Committee will be passed upon by the Council and the general business session of the Society and those approved will be published in the S.A.E. HANDBOOK.

Rejection or major changes in any of the reports will require that they be sent back to the Divisions that prepared them and that they cannot be passed upon again before the Semi-Annual Meeting of the Society next summer. In voting on the reports at the Standards Committee Meeting, the Regulations require that only members of the Standards Committee do so.

In the last year approximately 75 projects in various stages of progress have been scheduled before the several Divisions of the Standards Committee. A number of subjects were concluded at the Semi-Annual Meeting of the Society last June and this report contains the recommendations of Divisions on subjects that they feel can be adopted for publication in the 1932 edition of the S. A. E. HANDBOOK. Under the business conditions existing recently, carrying on the greater part of this work in Division meetings has not been possible, and consequently most of the reports submitted now have been developed largely through circularizing, direct correspondence and Division letter-ballots. A number of the following recommendations are accordingly published in this issue of THE JOURNAL considerably in advance of the completion of Division approval by letter-ballot, and accordingly are subject to the final returns of these ballots.

Aircraft Division

PERSONNEL

J. F. Hardecker, *Chairman*	Naval Aircraft Factory
Mac Short, *Vice Chairman*	Stearman Aircraft Co.
Lieut. R. S. Barnaby, U. S. N.	Bureau of Aeronautics, Navy Department
John R. Cautley	Bendix Brake Co.
C. H. Colvin	Pioneer Instrument Co., Inc.
R. C. Eaton	Sikorsky Aviation Corp.
G. G. Emerson	Wright Aeronautical Corp.
Lieut. C. B. Harper, U. S. N.	Baltimore
Major C. W. Howard, U. S. A.	Materiel Division, Air Corps
Charles E. Kirkbride	Naval Aircraft Factory
I. M. Laddon	Consolidated Aircraft Corp.
K. M. Lane	Ridgewood, N. J.
B. J. Lemon	United States Rubber Co.
C. J. McCarthy	Chance Vought Corp.
L. C. Milburn	Glenn L. Martin Co.
Proctor Nichols	Alexander Aircraft Co.
C. T. Porter	Keystone Aircraft Corp.
W. L. Smith	National Air Transport, Inc.
George I. Stich	Aero Supply Mfg. Co., Inc.
Edward Wallace	Cleveland Heights, Ohio
T. P. Wright	Curtiss Aeroplane & Motor Co., Inc.

The following recommendations are submitted in revision of the present specifications in the 1931 S.A.E. HANDBOOK. The reports are based on information obtained from the Tire & Rim Association, Inc., covering changes that have actually been adopted since the S.A.E. specifications were last published. The Aircraft Division accordingly submits them for approval and adoption.

Airplane Landing Wheel Tires—High Pressure Type

(Proposed Revision of S.A.E. Recommended Practice)

The only change proposed in the tables on pp. 15 and 16 of the July Supplement to the 1931 S.A.E. HANDBOOK is the maximum load per tire for the 44 x 10 size, which has been raised from 6300 lb. to 6500 lb.

Airplane Tire Valves

The specfication to be revised was last printed on page 20 of the July Supplement to the 1931 S.A.E. HANDBOOK.

(Proposed Revision of S.A.E. Recommended Practice)

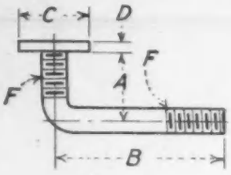
LOW-PRESSURE TYPE

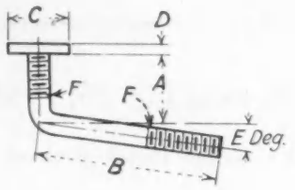
The only revision in this table at the bottom of p. 20 of the July Supplement to the 1931 S.A.E. HANDBOOK, has been to change dimension *E* for both valve sizes, to 9/64 in. instead of 5/32 and 3/16 in. respectively.

HIGH-PRESSURE TYPE

Valves Nos. 47, 48, 49, 64, 65 and 66, corresponding to the drawing for tire valves Nos. 43 and 44 on p. 20 of the

July Supplement to the 1931 S.A.E. HANDBOOK, have been added and the table of dimensions changed to the following. Valve TR 44 has been discontinued.





Valve No.[a]	Valve Dimensions					
	A	*B*	*C*	*D*	*E*, Deg.	*F*, Threads per Inch
TR 43[b,c]	5/8	1 1/2	5/8	1/16	0	0.302-32
TR 47[b]	1 1/2	4 3/32	1 1/4	1/16	0	0.482-26
TR 48[b]	1 1/2	4 15/16	1 1/4	1/16	0	0.482-26
TR 49[b]	1 1/2	4 3/32	13/16	1/16	0	0.302-32
TR 61[b]	1 5/32	1 5/8	13/16	1/16	20	0.302-32
TR 62[b]	2 3/4	2 1/8	13/16	1/16	39	0.302-32
TR 63[d]	2 3/8	3	13/16	1/16	30	0.302-32
TR 64[c,e]	41/64	2 1/4	13/16	1/16	0	0.302-32
TR 65[c,e]	41/64	3 1/4	13/16	1/16	0	0.302-32
TR 66[c,e]	41/64	4 1/4	13/16	1/16	0	0.302-32

[a] Tire & Rim Association valve number.
[b] Angle valve used with high-pressure sizes.
[c] Spreader not used.
[d] When used on 8-in. rim valve TR 63 may have $E=10$ deg. maximum tilt; when used on 10-in. rim valve TR 63 may have $E=17$ deg. maximum tilt.
[e] Angle valve used with low-pressure sizes.

Aircraft-Engine Division

PERSONNEL

Arthur Nutt, *Chairman*	Wright Aeronautical Corp.
Robert Insley, *Vice-Chairman*	Continental Aircraft Engine Co.
C. S. Fliedner	Bureau of Aeronautics, Navy Department
E. D. Herrick	Lycoming Mfg. Co.
Ludwig A. Majneri	Warner Aircraft Corp.
Capt. E. R. Page, U. S. A.	Materiel Division, Air Corps
M. J. Steele	Packard Motor Car Co.
Andrew V. D. Willgoos	Pratt & Whitney Aircraft Co.

Although the Division has not held a meeting since last April, the accompanying recommendations are submitted with letter-ballot approval of the Division members.

Propeller Blade-Ends

The proposed change in the table of propeller blade-ends is a correction in line with the corresponding dimension for the other sizes of these blade ends and was brought to the attention of the Division too late for it to be acted on by the Standards Committee last June.

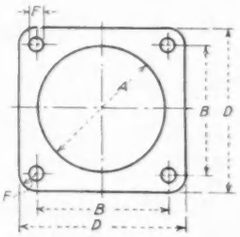
(Proposed Revision of S.A.E. Standard)

This recommendation refers to the S.A.E. Standard on p. 4 of the 1931 S.A.E. HANDBOOK and is to change diameter *B* for blade end No. 0 to 3.245 instead of 3.250 in. to bring this nominal diameter 0.005 in. under the bore of the blade socket, which is the standard practice with the other sizes of blade end.

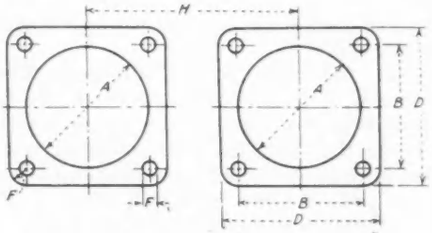
Aircraft Carbureter Flanges

The recommendation on carbureter flanges is the result of a study commenced over a year ago by the Division. Six types of flange were tentatively proposed and circularized among the aircraft engine and carbureter manufacturers for criticism. The results were discussed at the Division meeting in April last year at which time the draft and replies to the circular letter were referred to J. M. Miller of the Bendix Stromberg Carbureter Co. for review. Upon further checking with the Army Air Corps for military practice, the accompanying revised report by Mr. Miller was referred to the Division members for their approval by letter-ballot. Mr. Miller has also suggested that flange thicknesses be specified as a part of the recommendation and he stated he would subsequently submit a proposal.

(Proposed Revision of S.A.E. Standard)



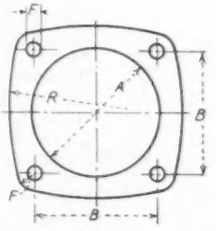
SINGLE BARREL FOUR-BOLT SQUARE FLANGE



DOUBLE BARREL EIGHT-BOLT FLANGE

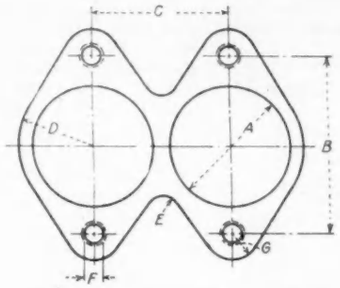
Nominal Size		*A*	*B*	*D*	*F*	*H*[f]
No.	Diameter					
2	1 1/4	1 7/16	1 3/4	2 5/16	9/32	.....
3	1 1/2	1 11/16	1 15/16	2 1/2	9/32	.....
4	1 3/4	1 15/16	2 3/16	2 3/4	9/32	4 3/8
5	2	2 3/16	2 11/32	3 1/32	11/32	4 7/8
6	2 1/4	2 7/16	2 1/2	3 5/16	11/32	5 1/8
7	2 1/2	2 11/16	2 3/4	3 1/2	11/32	5 1/2
8	2 3/4	2 15/16	3	3 11/16	11/32	5 7/8
9	3	3 3/16	3 3/16	4	13/32	.....
10[f]	3 1/4	3 7/16	3 7/16	4 3/8	15/32	6 5/16

[f] For double barrel, eight-bolt flange type only.



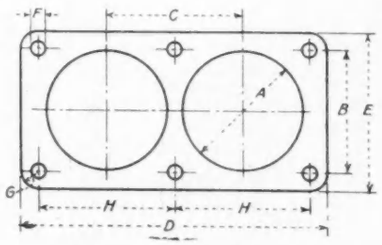
SINGLE BARREL FOUR-BOLT FLANGE

Nominal Size		*A*	*B*	*F*	*R*
No.	Diameter				
10	3 1/4	3 7/16	3 3/8	13/32	2 1/8
11	3 1/2	3 11/16	3 1/2	13/32	2 1/4
12	3 3/4	3 15/16	3 3/4	13/32	2 3/8
13	4	4 3/16	4	13/32	2 1/2



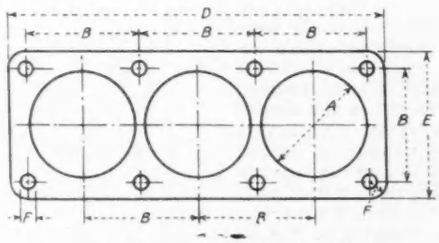
DOUBLE BARREL FOUR-BOLT FLANGE

Nominal Size								
No.	Diameter	*A*	*B*	*C*	*D*	*E*	Tap *F*	*G*
4	1¾	1 15/16	3 1/8	2 3/16	1 1/4	9/32	7/16-14	13/32
5	2	2 3/16	3 3/8	2 7/16	1 3/8	9/32	7/16-14	13/32
6	2¼	2 7/16	3 5/8	2 11/16	1 1/2	9/32	7/16-14	15/32
7	2½	2 11/16	4	2 15/16	1 21/32	9/32	7/16-14	15/32
8	2¾	2 15/16	4¼	3 3/16	1 25/32	9/32	7/16-14	17/32



DOUBLE BARREL SIX-BOLT FLANGE

Nominal Size									
No.	Diameter	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
7	2½	2 11/16	2 13/16	2 15/16	6 5/8	3 11/16	11/32	7/16	2 7/8
8	2¾	2 15/16	3	3 3/16	7 1/4	3 7/8	11/32	7/16	3 3/32
9	3	3 3/16	3 3/16	3 7/16	7 9/16	4 1/8	13/32	15/32	3 5/16
10	3¼	3 7/16	3 7/16	3 11/16	8 1/16	4 3/8	13/32	15/32	3 9/16
11	3½	3 11/16	3 11/16	3 15/16	8 9/16	4 5/8	13/32	15/32	3 13/16
12	3¾	3 15/16	3 15/16	4 3/16	9 1/16	4 7/8	13/32	15/32	4 1/16



TRIPLE BARREL EIGHT-BOLT FLANGE

Nominal Size						
No.	Diameter	*A*	*B*	*D*	*E*	*F*
3	1½	1 11/16	1 15/16	6 3/8	2½	9/32
4	1¾	1 15/16	2 3/16	7 1/8	2¾	9/32
5	2	2 3/16	2 7/16	8	3 1/8	11/32

Ball and Roller Bearings Division

PERSONNEL

G. R. Bott, *Chairman*	Norma-Hoffmann Bearings Corp.
E. R. Carter, *Vice-Chairman*	Fafnir Bearing Co.
H. E. Brunner	S.K.F. Industries, Inc.
F. H. Buhlman	Rollway Bearing Co., Inc.
D. F. Chambers	Bearings Co. of America
L. A. Cummings	Marlin-Rockwell Corp.
T. C. Delaval-Crow	New Departure Mfg. Co.
H. R. Gibbons	Hyatt Bearings Division of General Motors Corp.
K. L. Herrmann	Bantam Ball Bearing Co.
H. N. Parsons	Chicago
Ernest Wooler	Timken Roller Bearing Co.

At the meeting of the Division in New York City on Dec. 8, the following reports were approved for submission to the Standards Committee and Society, for adoption and publication in the 1932 edition of the S.A.E. HANDBOOK.

Annular Ball Bearings—Single Row—Light Series

The recommended revision in the shaft shoulder height for bearing No. 39 in the light series of the single-row annular ball bearings, was suggested at the International Conference at Copenhagen, to eliminate the differences in these dimensions between the present American Standard and the International Standard bearings. The Division at its meeting felt that increasing the present shoulder shaft height from 1 to 2.5 mm. (0.039 to 0.098 in.) would make the height of the shoulder greater than the height of the inner ring of this bearing. Accordingly the Division modified this change to that given in the accompanying recommendation for adoption in revision of the present S.A.E. Standard on p. 308 of the 1931 S.A.E. HANDBOOK. It recommends that the same change be made in the present American Standard.

(Proposed Revision of S.A.E. Standard)

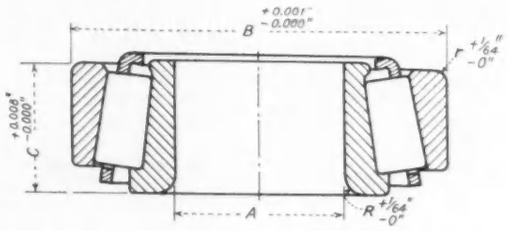
Change the radius r of the shaft and housing fillet from 0.4 mm. (0.016 in.) to 0.6 mm. (0.024 in.) and the shoulder height H from 1.0 mm. (0.039 in.) to 1.5 mm. (0.059 in.).

Roller Bearings

The accompanying report on taper roller bearings is the result of many years of study by the Division. About five years ago, a list of over 250 roller bearing sizes and their combinations of cups and cones were first published in the S.A.E. HANDBOOK. At about this time a proposal was advanced in several European countries for an international standard on metric roller bearings interchangeable with the international standard for ball bearings. This proposal was reviewed through the national standardizing bodies of the countries affiliated with the International Standards Association and again presented at an International Conference on bearings in Copenhagen last May. At that conference, Ernest Wooler, who was the delegate of the Ball and Roller Bearings Division, demonstrated the impracticability of a taper roller bearing standard that would provide for interchangeability with metric ball bearings and presented a proposal that he had developed and that had been discussed by the Division just prior to his sailing for Europe, which would materially reduce the number of standard taper roller bearing sizes. This proposal was well received and the understanding was that Mr. Wooler would develop it further with the idea that the final proposal would become both an American as well as International Standard for inch-dimension bearings, without attempting to make them interchangeable with the ball bearings. Since the International Conference, Mr. Wooler has prepared the accompanying recommendation which includes 21 bearings in a light series, 19 in a medium series and 18 in a heavy series, a total of 58 bearings ranging in bore from 3/8 to 4¼ in. selected from over 1000 bearings that are in most extensive use. As the bearings in the accompanying tables include the range of sizes used for practically all automotive purposes, the report is submitted at this time for adoption as

S.A.E. Standard to replace the present Standard commencing on p. 334 of the 1931 S.A.E. HANDBOOK. The Division is also referring this recommendation to the Sectional Committee on Ball Bearings for which the Society is one of the sponsors under procedure of the American Standards Association, for approval as American Standard and also for submission to the European countries for their acceptance and approval as International Standard. It is contemplated that these series of bearings will be extended to include larger sizes for industrial applications, such as on railroads, mill machinery and rolling mills, as their development warrants.

(Proposed Revision of S.A.E. Standard)



ROLLER BEARINGS

Light Series							Medium Series							Heavy Series						
Standard No.	Present No.	A	B	C	R	r	Standard No.	Present No.	A	B	C	R	r	Standard No.	Present No.	A	B	C	R	r
L037	A2037–A2126	0.375	1.2595	0.394	3/64	3/64														
L050	A4050–A4138	0.500	1.3775	0.433	3/64	3/64														
L062	03062–03162	0.625	1.625	0.5625	3/64	3/64														
L075	05075–05185	0.750	1.8504	0.5662	3/64	3/64	M075	09078–09195	0.750	1.938	0.7813	3/64	3/64							
L087	07087–07204	0.875	2.047	0.591	3/64	3/64	M087	1755–1729	0.875	2.240	0.7625	3/64	3/64							
L100	1986–1932	1.000	2.3125	0.750	3/64	3/64	M100	1986–1931	1.000	2.375	0.7813	3/64	3/64	H100	2687–2631	1.000	2.615	0.9375	3/64	3/64
L112	15112–15250	1.125	2.500	0.8125	3/64	3/64	M112	2689–2631	1.125	2.615	0.9375	3/64	3/64	H112	3198–3120	1.125	2.8593	1.1875	3/64	1/8
L125	14125–14276	1.250	2.717	0.7813	3/64	3/64	M125	2582–2523	1.250	2.750	0.9375	3/64	3/64	H125	3476–3420	1.250	3.125	1.1563	3/64	1/8
L137	16137–16284	1.375	2.844	0.8125	3/64	3/64	M137	2796–2720	1.375	3.000	0.9375	3/64	1/8	H137	3379–3328	1.375	3.3125	1.1563	3/64	1/8
L150	28151–28300	1.500	3.000	0.8125	3/64	3/64	M150	2788–2734	1.500	3.125	1.000	3/64	1/8	H150	3583–3525	1.500	3.4375	1.1875	3/64	1/8
L162	342–332	1.625	3.1496	0.8268	3/64	3/64	M162	3383–3328	1.625	3.3125	1.1563	3/64	1/8	H162	447–432X	1.625	3.750	1.250	3/64	1/8
L175	355X–354A	1.750	3.3464	0.8125	3/64	3/64	M175	3578–3525	1.750	3.4375	1.1875	3/64	1/8	H175	527–522	1.750	4.000	1.375	3/64	1/8
L187	369A–362A	1.875	3.500	0.8125	3/64	3/64	M187	3779–3720	1.875	3.6718	1.1875	3/64	1/8	H187	536–532X	1.875	4.250	1.4375	3/64	1/8
L200	375S–374	2.000	3.6718	0.8125	3/64	3/64	M200	3780–3732	2.000	3.875	1.1875	3/64	1/8	H200	537–532A	2.000	4.375	1.500	3/64	1/8
L225	387A–383	2.250	3.937	0.8268	3/64	3/64	M225	469–453X	2.250	4.125	1.1875	3/64	1/8	H225	555S–552A	2.250	4.875	1.500	3/64	1/8
L250	395–394A	2.500	4.3307	0.8661	3/64	3/64	M250	3982–3920	2.500	4.4375	1.1875	3/64	1/8	H250	639–632	2.500	5.375	1.625	3/64	1/8
L275	New Series	2.750	4.6875	1.000	3/64	1/8	M275	482–472X	2.750	4.875	1.1875	3/64	1/8	H275	745A–742	2.750	5.909	1.750	3/64	1/8
L300	34301–34500	3.000	5.000	1.0625	3/64	1/8	M300	495A–492A	3.000	5.250	1.3125	3/64	1/8	H300	755–752	3.000	6.375	1.875	3/64	1/8
L325	495–493	3.250	5.375	1.1875	3/64	1/8	M325	580–572	3.250	5.5115	1.4375	3/64	1/8	H325	757–753	3.250	6.625	1.875	3/64	1/8
L350	New Series	3.500	5.625	1.1875	3/64	1/8	M350	593–592A	3.500	6.000	1.5625	3/64	1/8	H350	775–772	3.500	7.125	1.875	3/16	1/8
L375	42376–42587	3.750	5.875	1.250	3/64	1/8	M375	52375–52638	3.750	6.375	1.5625	3/64	1/8	H375	864–854	3.750	7.500	2.250	3/16	1/8
							M400	687–672	4.000	6.625	1.625	3/64	1/8	H400	861–854X	4.000	7.875	2.4375	3/16	1/8
														H425	936–932	4.250	8.375	2.625	3/16	1/8

Note.—All bearing bores of 2½ in. or smaller have a tolerance of $\frac{+.0005}{-.0000}$ in., over 2½ in. bores have tolerance of $\frac{+.001}{-.000}$ in.

Ball-Bearing Lock-Nuts and Washers

The recommendation on ball-bearing lock-nuts and washers relates only to the threads on the shaft and in the lock nut in the present S.A.E. Recommended Practice commencing on p. 44 of the July Supplement to the 1931 S.A.E. HANDBOOK. A year ago the pitches of these threads were revised, but the limit dimensions then published were according to old manufacturing practice. A Subdivision of the Screw-Threads Division was appointed at the request of the Ball and Roller Bearings Division to revise the thread dimensions in accordance with the American (National) Fine Standard, Class 3 Fit. The Subdivision, of which Earle Buckingham is chairman, reported the accompanying tables to the Ball and Roller Bearings Division which now recommends them for adoption by the Society. It also recommends that the revised specification be adopted as S.A.E. Standard.

(Proposed Revision of S.A.E. Recommended Practice)

TABLE 1—SHAFTS

Lock-Nut No.	Threads per Inch	Major Diameter			Pitch Diameter			Maximum Minor Diameter
		Maximum	Tolerance	Minimum	Maximum	Tolerance	Minimum	
0	32	0.391	0.0054	0.3856	0.3707	0.0024	0.3683	0.3527
1	32	0.469	0.0054	0.4636	0.4487	0.0026	0.4461	0.4307
2	32	0.586	0.0054	0.5806	0.5657	0.0027	0.5630	0.5477
3	32	0.664	0.0054	0.6586	0.6437	0.0029	0.6408	0.6257
4	32	0.781	0.0054	0.7756	0.7607	0.0030	0.7577	0.7427
5	32	0.969	0.0054	0.9636	0.9487	0.0032	0.9455	0.9307
6	18	1.173	0.0082	1.1648	1.1369	0.0038	1.1331	1.1048
7	18	1.376	0.0082	1.3578	1.3399	0.0039	1.3360	1.3078
8	18	1.563	0.0082	1.5548	1.5269	0.0042	1.5227	1.4948
9	18	1.767	0.0082	1.7588	1.7309	0.0043	1.7266	1.6988
10	18	1.968	0.0082	1.9598	1.9319	0.0045	1.9274	1.8998
11	18	2.157	0.0082	2.1488	2.1209	0.0046	2.1163	2.0888
12	18	2.360	0.0082	2.3518	2.3239	0.0047	2.3192	2.2918
13	18	2.548	0.0082	2.5398	2.5119	0.0049	2.5070	2.4798
14	18	2.751	0.0082	2.7428	2.7149	0.0049	2.7100	2.6828
15	12	2.933	0.0112	2.9218	2.8789	0.0054	2.8735	2.8308
16	12	3.137	0.0112	3.1258	3.0829	0.0055	3.0774	3.0348
17	12	3.340	0.0112	3.3288	3.2859	0.0057	3.2802	3.2378
18	12	3.527	0.0112	3.5158	3.4729	0.0058	3.4671	3.4248
19	12	3.730	0.0112	3.7188	3.6759	0.0059	3.6700	3.6278
20	12	3.918	0.0112	3.9068	3.8639	0.0061	3.8578	3.8158
21	12	4.122	0.0112	4.1108	4.0679	0.0062	4.0617	4.0198
22	12	4.325	0.0112	4.3138	4.2709	0.0063	4.2646	4.2228
24	12	4.716	0.0112	4.7048	4.6619	0.0065	4.6554	4.6138
26	12	5.106	0.0112	5.0948	5.0519	0.0067	5.0452	5.0038
28	12	5.497	0.0112	5.4858	5.4429	0.0069	5.4360	5.3948
30	12	5.888	0.0112	5.8768	5.8339	0.0072	5.8267	5.7858
32	8	6.284	0.0152	6.2688	6.2028	0.0078	6.1950	6.1306
34	8	6.659	0.0152	6.6438	6.5778	0.0080	6.5698	6.5056
36	8	7.066	0.0152	7.0508	6.9848	0.0082	6.9766	6.9126
38	8	7.472	0.0152	7.4568	7.3908	0.0083	7.3825	7.3186
40	8	7.847	0.0152	7.8318	7.7658	0.0085	7.7573	7.6936

American (National) Standard Fine, Class 3 Fit.

TABLE 2—LOCK-NUTS

Lock-Nut No.	Threads per Inch	Minimum Major Diameter	Pitch Diameter			Minor Diameter		
			Minimum	Tolerance	Maximum	Minimum	Tolerance	Maximum
0	32	0.391	0.3707	0.0024	0.3731	0.3572	0.0034	0.3606
1	32	0.469	0.4487	0.0026	0.4513	0.4352	0.0034	0.4386
2	32	0.586	0.5657	0.0027	0.5684	0.5522	0.0034	0.5556
3	32	0.664	0.6437	0.0029	0.6466	0.6302	0.0034	0.6336
4	32	0.781	0.7607	0.0030	0.7637	0.7472	0.0034	0.7506
5	32	0.969	0.9487	0.0032	0.9519	0.9352	0.0034	0.9386
6	18	1.173	1.1369	0.0038	1.1407	1.1129	0.0060	1.1189
7	18	1.376	1.3399	0.0039	1.3438	1.3159	0.0060	1.3219
8	18	1.563	1.5269	0.0042	1.5311	1.5029	0.0060	1.5089
9	18	1.767	1.7309	0.0043	1.7352	1.7069	0.0060	1.7129
10	18	1.968	1.9319	0.0045	1.9364	1.9079	0.0060	1.9139
11	18	2.157	2.1209	0.0046	2.1255	2.0969	0.0060	2.1029
12	18	2.360	2.3239	0.0047	2.3286	2.2999	0.0060	2.3059
13	18	2.548	2.5119	0.0049	2.5168	2.4879	0.0060	2.4939
14	18	2.751	2.7149	0.0049	2.7198	2.6909	0.0060	2.6969
15	12	2.933	2.8789	0.0054	2.8843	2.8428	0.0090	2.8518
16	12	3.137	3.0829	0.0055	3.0884	3.0468	0.0090	3.0558
17	12	3.340	3.2859	0.0057	3.2916	3.2498	0.0090	3.2588
18	12	3.527	3.4729	0.0058	3.4787	3.4368	0.0090	3.4458
19	12	3.730	3.6759	0.0059	3.6818	3.6398	0.0090	3.6488
20	12	3.918	3.8639	0.0061	3.8700	3.8278	0.0090	3.8368
21	12	4.122	4.0679	0.0062	4.0741	4.0318	0.0090	4.0408
22	12	4.325	4.2709	0.0063	4.2772	4.2348	0.0090	4.2438
24	12	4.716	4.6619	0.0065	4.6684	4.6258	0.0090	4.6348
26	12	5.106	5.0519	0.0067	5.0586	5.0158	0.0090	5.0248
28	12	5.497	5.4429	0.0069	5.4498	5.4068	0.0090	5.4158
30	12	5.888	5.8339	0.0072	5.8411	5.7978	0.0090	5.8068
32	8	6.284	6.2028	0.0078	6.2106	6.1487	0.0135	6.1622
34	8	6.659	6.5778	0.0080	6.5858	6.5237	0.0135	6.5372
36	8	7.066	6.9848	0.0082	6.9930	6.9307	0.0135	6.9442
38	8	7.472	7.3908	0.0083	7.3991	7.3367	0.0135	7.3502
40	8	7.847	7.7658	0.0085	7.7743	7.7117	0.0135	7.7252

American (National) Standard Fine, Class 3 Fit.

Electrical Equipment Division

PERSONNEL

D. M. Pierson, *Chairman*	Chrysler Corp.
D. S. Cole, *Vice-Chairman*	Leece-Neville Co.
Azel Ames	Kerite Insulated Wire & Cable Co.
A. K. Brumbaugh	White Motor Co.
C. F. Gilchrist	Electric Auto-Lite Co.
W. S. Haggott	Packard Electric Co.
W. H. Hutchins	Delco Appliance Corp.
L. M. Kanters	Waukesha Motor Co.
A. R. Lewellen	Chevrolet Motor Co.
L. E. Lighton	Electric Storage Battery Co.
L. O. Parker	Delco-Remy Corp.
A. J. Poole	Bendix Aviation Corp.
E. K. Schadt	Cadillac Motor Car Co.
T. E. Wagar	Studebaker Corp.

The following reports of the Division, which were acted on at its meeting on Dec. 14, have been in progress for a considerable time and are now submitted to the Standards Committee and Society for adoption and publication in the 1932 S.A.E. HANDBOOK.

Starting-Motor Circuits

In August, 1918, the Society adopted a specification for the maximum lengths of starting-motor cable in three cable sizes, based on an allowable drop of 0.3 volt at 500 amp. In January, 1930, this standard was cancelled as obsolete. Now the Division feels that a suitable recommendation should be included in the S.A.E. HANDBOOK as a guide in the laying out of this circuit in motor vehicles and accordingly recommends the adoption of the following for S.A.E. Standard. This is considered good practice and is in accordance with the recommendation of the Automotive Electric Association.

(Proposed S.A.E. Standard)

The starting-motor circuits in motor vehicles shall be designed so that the difference between the voltage at the storage-battery terminals and the voltage at the starting-motor terminals shall not exceed 0.12 volt per 100 amp., with the circuit at a normal temperature of 68 deg. fahr.

Non-Metallic Conduit

About a year ago a Subdivision was appointed to bring the present S.A.E. Recommended Practice commencing on p. 232 of the 1931 S.A.E. HANDBOOK uptodate. L. O. Parker, who was appointed a Subdivision of one, drafted a proposal that was circularized for comment, the result of which was a number of constructive criticisms. Mr. Parker revised the draft which was again circularized and considered at the meeting of the Division and recommended for approval in the accompanying form.

(Proposed Revision of S.A.E. Recommended Practice)

General Information.—Non-metallic flexible conduit or loom is recommended for use as an insulated covering giving mechanical protection over insulated wire, metal tubing or other parts requiring a water, oil and acid-proof covering resistant to fire or abrasion. It is also recommended for use as a covering for copper or other metal tubing to prevent crystallization and to eliminate rattles.

Construction.—The loom shall be of single-wall construction; the material used to be strictly non-metallic and of sufficient mechanical strength so that when formed or woven into a tubing it shall

pass the tests for the size specified. Finished loom shall be free from obstruction and shall permit easy introduction of the maximum size wire or other part for which it is normally suited. Loom in any length shall slip freely over a polished mandrel 12 in. long and equal in diameter to the minimum inside-diameter specified. The dimensions of the standard sizes are listed in the accompanying table. Alternate dimensions for the three sizes indicated in the table are for loom that can be used with standard ferrules.

DIMENSIONS OF NON-METALLIC CONDUIT

Nominal Size, In.	Inside Diameter, In. Minimum	Inside Diameter, In. Maximum	Outside Diameter, In. Minimum	Outside Diameter, In. Maximum
3/16[g]	0.187	0.207	0.277	0.297
3/16	0.187	0.207	0.287	0.307
1/4[g]	0.250	0.270	0.340	0.360
1/4	0.250	0.270	0.350	0.370
5/16	0.312	0.332	0.412	0.432
3/8[g]	0.375	0.395	0.475	0.495
3/8	0.375	0.395	0.505	0.525
7/16	0.437	0.457	0.567	0.587
1/2	0.500	0.520	0.630	0.650
9/16	0.562	0.582	0.722	0.742
5/8	0.625	0.645	0.785	0.805
11/16	0.687	0.707	0.847	0.867
3/4	0.750	0.770	0.934	0.954
13/16	0.812	0.832	0.996	1.016
7/8	0.875	0.895	1.079	1.099
15/16	0.937	0.957	1.141	1.161
1	1.000	1.020	1.204	1.224

[g] For use with standard ferrules.

Saturation.—(*a*) For a fire-resistant loom the inside and outside shall be thoroughly impregnated with an asphaltic compound or an equivalent water, acid and fire-resisting compound. (*b*) For a general-purpose loom the inside and outside shall be thoroughly impregnated with an asphaltic compound or an equivalent water and acid-resisting compound. (*c*) For an oil-proof loom not affected by gasoline or baking varnish the inside and outside shall be thoroughly impregnated with a gum saturator or its equivalent. The saturator, when dry, shall be free from tackiness and gummy deposits. This impregnation is introduced to prevent absorption of moisture, oil or gasoline, to bind the material together to give the required wall strength and to prevent fraying.

Finish.—(*a*) For a fire-resistant loom the outer surface shall be thoroughly covered by an asphaltic or equivalent water, acid and fire-resisting compound. (*b*) For a general-purpose loom the outer surface shall be thoroughly covered with at least two coats of black pyroxylin lacquer or its equivalent, producing a good luster and a good bond to the fabric. (*c*) For an oil-proof loom the outer surface shall be thoroughly covered with at least two coats of black pyroxylin lacquer or its equivalent, producing a good luster and a good bond to the fabric. The lacquer must be thoroughly dried before wrapping or boxing the loom for shipment. The use of heavy finishes or saturators to give artificial appearance is not permitted. The pyroxylin must be sufficiently plasticized so that it will not crack on a piece of loom kept three months at room temperature and then bent back sharply upon itself. Loom with finish of a higher luster than can be obtained with two coats of lacquer as specified above shall be considered special and should be covered by other specifications when required.

Tests.—(*a*) A 6-in. piece of loom totally immersed in water at 70 deg. fahr. for 24 hr. and then blown out with a mild air current immediately after removing the water shall not have an increase in weight of more than 35 per cent. (*b*) The wall must not collapse when the loom is bent to a radius of five times the inside diameter at 70 deg. fahr. The compound and finish must not crack open in this test. The material in the wall of the loom shall not crack or break when a 3-in. length is flattened between the jaws of a vise, in accordance with the following table. The finish shall not show excessive cracking when loom is subjected to this test.

Inside Diameter of Loom, in.	3/8 and under	Over 3/8
Distance between Jaws, in.	11/64	9/32

The polished mandrels used for checking the inside diameters shall show no sticking or discoloration up to 150 deg. fahr.

(*c*) Loom shall be capable of standing a tension test for 5 min. without breaking or opening at any point as follows:

Loom, Nominal Size, In.	Minimum Tensile Requirement, Lb.
3/16	75
1/4	85
5/16 and 3/8	100
7/16 or larger	150

The test piece shall be 6 in. long between supports.

Additional Test for the Oil-Proof and Fire-Resistant Loom.—When a piece of loom is totally immersed in an equal mixture of cylinder oil, kerosene and gasoline at 70 deg. fahr. for 5 min. and then subjected to a temperature not exceeding 250 deg. fahr. for 1 hr., the saturating compound must not drip from the loom or the finish show any appreciable defects.

Fireproofing.—Flame-resisting qualities shall be incorporated in the saturation or finish, or both, to pass the following test: The loom shall not convey fire nor support combustion for more than 1 min. after five 15-sec. applications of a standard test-flame with intervals of 15 sec. between applications. A standard test-flame is the blue flame, about 5 in. high, produced by a ½-in. Bunsen burner fed with ordinary illuminating gas at normal pressure. The loom shall be held vertically with either the lower or the upper end thoroughly sealed to prevent the passage of air, and the flame must be applied horizontally.

Storage-Batteries

The recommendations on the storage-batteries are in the nature of a revision of the present Standard commencing on p. 196 of the 1931 S.A.E. HANDBOOK to bring them into accord primarily with batteries that are being used on current models of motor vehicle and that are expected to be used on future models. Although this Standard is intended primarily for use as original equipment, it will have an effect on the replacement business after the motor vehicles now being made have been in operation. Accordingly the National Battery Manufacturers Association was furnished with the proposal and considered it with the Division, that Association having been represented at the Division meeting.

(Proposed Revision of S.A.E. Recommended Practice)

GENERAL SPECIFICATIONS

Application.—These specifications are intended to apply only to lead-acid storage-batteries for automotive equipment.

Ratings.—Batteries for combined starting and lighting service shall have three ratings, except as noted. The first rating shall indicate the lighting ability and shall be the capacity in ampere-hours of the battery when it is discharged continuously to an average final terminal voltage equivalent to 1.75 per cell, the temperature of the battery at the beginning of such discharge being 80 deg. fahr., and an average temperature of 80 deg. fahr. being maintained during discharge, with a maximum variation of ±5 deg. fahr. from 80 deg. fahr. at the 20-hr. rate for passenger-car and motor-truck service and at the 8-hr. rate for motorcoach service. New batteries shall meet these ratings on or before the third discharge when discharged at a rate in amperes obtained by dividing the rated capacity in ampere-hours, as shown in the following tables, by the number of hours at which the rating is specified. The second rating shall be the minimum amperes when the battery is discharged continuously at the 20-min. rate to an average final terminal voltage equivalent to 1.5 per cell, the temperature of the battery at the beginning of such discharge being 80 deg. fahr. New batteries shall meet this rating on or before the third discharge, when discharged at the rate in amperes specified in the following tables. The third rating shall apply only to batteries used in passenger-car and motor-truck starting and lighting service. This rating shall indicate the cranking ability at low temperature, and shall be the minimum time in minutes when the battery is discharged continuously at 300 amp. to an average final terminal voltage equivalent to 1 volt per cell, the temperature of the battery at the beginning of such discharge being 0 deg. fahr. The batteries shall be prepared for this test by being placed in an atmosphere of 0 deg. fahr. ±1 deg. fahr. for not less than 24 consecutive hr. and are to be tested in an atmospheric temperature of 0 deg. fahr. New batteries shall meet this rating on the first discharge of a battery which has been fully charged following an initial discharge for 5 hr. at a rate in amperes equal to one-seventh of the 20-min. rate in amperes specified in the following tables, the temperature of the battery at the beginning of such preliminary discharge being 80 deg. fahr.

Location of Battery Parts.—The location and polarity of the

terminal posts and the position of handles when used, shall be as shown in the accompanying illustration.

Type Designations.—Type letters, numbers or symbols, which shall enable the user to determine ratings from the makers' catalogs, shall be stamped or molded on the case or cell connectors, or on a name plate attached to the end or side of the battery.

Terminal Posts.—Polarity shall be plainly marked as follows: The positive post shall be marked Pos or P or +. When taper posts are used for terminals of lead-acid storage-batteries, the dimensions in inches shall be

Small Diameter of Negative Post, in.	5/8
Small Diameter of Positive Post, in.	11/16
Minimum Length of Taper, in.	5/8
Taper per Foot, Included Angle, in.	1 1/3

PASSENGER CAR BATTERIES

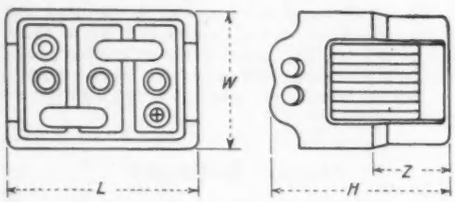


FIG. 1

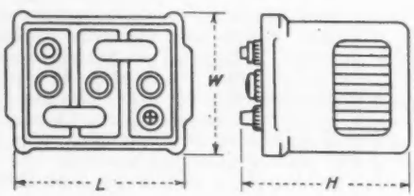


FIG. 2

TABLE 1—LOW-PLATE TYPE (SEE FIG. 1 OR 2)

Battery No.	No. of Cells	Minimum Capacity at 20-Hr. Rate, Amp-Hr.	Minimum Current for 20 Min., Amp.	Minimum Time at 300 Amp. and 0 Deg. Fahr., Min.	Maximum Over-All Dimensions, In.		
					Length[a] *L*	Width *W*	Height *H*
1	3	85	100	1.70	9 1/8	7 1/4	9 1/4
2	3	99	117	2.75	10 3/8	7 1/4	9 1/4
3	3	113	133	3.75	11 3/4	7 1/4	9 1/4
4	3	128	150	4.75	13 1/2	7 1/4	9 1/4
5	3	142	167	5.75	14 1/2	7 1/4	9 1/4

TABLE 2—HIGH-PLATE TYPE (SEE FIG. 1 OR 2)

Battery No.	No. of Cells	Minimum Capacity at 20-Hr. Rate, Amp-Hr.	Minimum Current for 20 Min., Amp.	Minimum Time at 300 Amp. and 0 Deg. Fahr., Min.	Maximum Over-All Dimensions, In.		
					Length[a] *L*	Width *W*	Height *H*
6	3	90	105	1.80	9 1/8	7 1/8	9 3/4
7	3	108	126	3.00	10 3/8	7 1/8	9 3/4
8	3	126	147	4.25	11 3/4	7 1/8	9 3/4
9	3	144	168	5.50	13 1/2	7 1/8	9 3/4
10	3	162	189	6.75	14 1/2	7 1/8	9 3/4

[a] Length dimensions do not include the ledge-type handles used on some types of rubber or composition case (See Fig. 2). This ledge shall not increase the case length more than 1¼ in. or extend downward more than ¾ in.

Dimension Z, Fig. 1, shall not exceed 3½ in.

MOTOR-TRUCK BATTERIES

These specifications are intended to apply only to lead-acid storage-batteries for heavy-duty motor-trucks. Where passenger-car types of battery are used for lighter trucks, passenger-car storage-battery specifications shall apply.

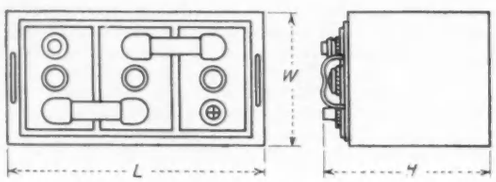


FIG. 3

TABLE 3—MOTOR-TRUCK BATTERY DIMENSIONS (SEE FIG. 3)

Battery No.	No. of Cells	Minimum Capacity at 20-Hr. Rate, Amp-Hr.	Minimum Current for 20 Min., Amp.	Minimum Time at 300 Amp. and 0 Deg. Fahr., Min.	Maximum Over-All Dimensions, In.		
					Length[c] *L*	Width *W*	Height *H*
11	3	67	....	....	10 1/4	7 5/8	10 5/8
12	3	89	....	....	12 1/2	7 5/8	10 5/8
13	3	105	120	1.50	13 3/8	7 5/8	10 5/8
14	3	123	140	2.75	15 7/8	7 5/8	10 5/8
15	3	140	160	4.00	17 1/4	7 5/8	10 5/8

[c] Length dimensions do not include the ledge-type handles used on some types of rubber or composition case (See Fig. 2). This ledge shall not increase the case length more than 1¼ in. or extend downward more than ¾ in.

Batteries Nos. 11 and 12 are for lighting service only; batteries Nos. 13, 14 and 15 are for combined starting and lighting service.

MOTORCOACH BATTERIES

These specifications are intended to apply only to lead-acid storage-batteries for motorcoaches.

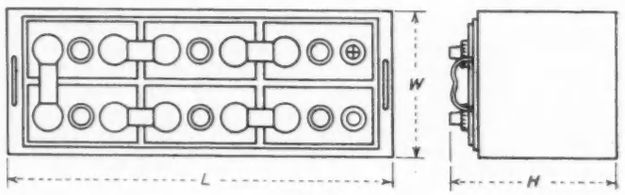


FIG. 4

TABLE 4—MOTORCOACH BATTERY DIMENSIONS (SEE FIGS. 3 OR 4)

Battery No.	No. of Cells	Minimum Capacity at 8-Hr. Rate, Amp-Hr.	Minimum Current for 20 Min., Amp.	Maximum Over-All Dimensions, In.		
				Length	Width	Height
22	3[j]	129	157	19 1/2	7 5/8	10 7/8
23	3[j]	178	225	26 1/4	7 5/8	10 7/8
25	6[k]	88	112	21 5/16	9 3/4	10 7/8
26	6[k]	104	135	21 5/16	11 7/16	10 7/8
27	6[k]	118	160	21 5/16	11 7/16	10 5/8

[j] Side to side assembly of cells (Fig. 3).
[k] Double row end-to-end assembly of cells (Fig. 4).

Distributor-Mountings and Nomenclature

Since the present standard for Timer-Distributor Mountings and the standard nomenclature for this part were adopted, the feeling has arisen that the titles for these parts should be simplified in the standards, and accordingly the Division recommends the following revision of the standards referred to.

(Proposed Revision of S.A.E. Standards)

Change the title of the S.A.E. Standard for Timer-Distributor Mountings on p. 182 of the 1931 S.A.E. HANDBOOK to read Distributor Mountings. Also change the references on pp. 617 and 618 under the standard Automobile Nomenclature to read Distributor instead of Timer-Distributor.

Storage-Battery Terminals

Because of the marked tendency to use storage-battery terminals that are inadequately protected against acid corrosion, the Division recommends that the following note be

added to the general information under the S.A.E. Standard for Storage-Battery Terminals, p. 210 of the 1931 S.A.E. HANDBOOK.

(Proposed Addition to S.A.E. Standard)

The terminals for storage-batteries, including their bolts and nuts, should be thoroughly lead coated.

Gasoline-Engine Division

PERSONNEL

E. S. Marks, *Chairman*	H. H. Franklin Mfg. Co.
J. B. Fisher, *Vice-Chairman*	Waukesha Motor Co.
R. J. Broege	International Engineering Corp.
E. D. Herrick	Lycoming Mfg. Co.
Lewis P. Kalb	Continental Motors Corp.
E. T. Larkin	Sterling Engine Co.
A. F. Milbrath	Wisconsin Motor Mfg. Co.
Harold G. Smith	Hercules Motors Corp.
Ralph R. Teetor	Perfect Circle Co.
Vincent C. Young	International Motor Co.

The accompanying recommendations of this Division are submitted for approval by the Society following their consideration at a meeting of the Division on Dec. 15.

Crankcase Drain-Plugs

The Division in reviewing the present S.A.E. Recommended Practice, p. 79 of the 1931 S.A.E. HANDBOOK, felt that the ⅜ in.-18 pipe plug is too small for crankcase drains and recommends its elimination from the specification as the ½ in.-14 plug will be small enough for such use. As a ¾ in.-14 pipe plug is used extensively, the Division has included it in the following proposed revision of the present S.A.E. Recommended Practice. The widths across flats for the square heads on the ½ and ¾-in. pipe plug sizes has been changed to conform with the manufacturers' standard for stock plugs.

(Proposed Revision of S.A.E. Recommended Practice)

Diameter	Threads per Inch[l]	Head	Width across Flats[m]
1/2	14 (pipe)	Square	9/16 (0.566)
3/4	14 (pipe)	Square	5/8 (0.629)
7/8	18	Hexagon	1⅛

[l] American (National) Standard Form.

[m] Figures in ( ) represent minimum wrench opening in American Standard.

Silent Chains

The Division's recommendation to cancel the present S.A.E. Standard for Silent Chains printed on p. 132 of the 1931 edition of the S.A.E. HANDBOOK is founded largely on a study that was made by the Sectional Committee on Power Transmission Chains and Sprockets, for which the Society is a sponsor, which indicated that standardizing silent chains is almost impossible because of the differences in their design by different manufacturers and the many variables that have to be taken into consideration for their satisfactory operation in different makes and models of engine. The present Standard was originally adopted by the Society in 1917 but has evidently outlived its usefulness in the rapid development of automotive equipment.

(Proposed Cancellation of S.A.E. Standard)

It is recommended that the present S.A.E. Standard, p. 132 of the 1931 S.A.E. HANDBOOK, be cancelled because of obsolescence.

Iron and Steel Division

PERSONNEL

F. P. Gilligan, *Chairman*	Henry Souther Engineering Corp.
A. H. D'Arcambal, *Vice-Chairman*	Pratt & Whitney Co.
J. R. Adams	Midvale Co.
A. L. Boegehold	General Motors Corp.
Henry Chandler	Vanadium Corp. of America
Bishop Clements	Wright Aeronautical Corp.
B. H. Delong	Carpenter Steel Co.
N. L. Deuble	Republic Steel Corp.
H. J. Fischbeck	Pratt & Whitney Aircraft Co.
H. W. Graham	Jones & Laughlin Steel Corp.
W. G. Hildorf	Timken Steel & Tube Co.
E. J. Janitzky	Illinois Steel Co.
J. B. Johnson	Materiel Division, Air Corps
W. J. MacKenzie	Republic Steel Corp.
J. A. Mathews	Crucible Steel Co. of America
W. C. Peterson	Detroit
S. P. Rockwell	Stanley P. Rockwell Co.
R. B. Schenck	Buick Motor Co.
H. P. Tiemann	Carnegie Steel Co.
E. W. Upham	Chrysler Motors
J. M. Watson	Hupp Motor Car Corp.
T. H. Wickenden	International Nickel Co.
Henry Wysor	Bethlehem Steel Co.
O. B. Zimmerman	International Harvester Co.

Physical Property Charts

The physical property charts in the iron and steel specifications published in the 1931 S.A.E. HANDBOOK have been a valuable feature of the specifications since their adoption in 1912. The present charts indicate normal minimum physical properties that may be expected from the several steels by normal heat-treatment, but the use of more greatly stressed parts of reduced weight, better wear-resisting characteristics and more skillful designing to prevent failures after machining in modern manufacturing led to the conclusion by the Division that the most effective use of these specifications has become as much a function of the designing engineer using steels as it is that of the metallurgist. This led to a further careful study by the Division of physical properties about five years ago and the appointment of a Subdivision, under the chairmanship of T. H. Wickenden, which conducted a long series of tests with the cooperation of 28 other companies on selected samples of S.A.E. Steels No. 3130 and 6130, the results of which were used by E. J. Janitzky to develop frequency and probability curves rather than straight-lines curves of averages alone, as the results expressed as minimum and maximum values within which users of the charts might expect to obtain satisfactory results were thought to be more valuable than the present charts in the specifications. The program was largely a development one and, because of the great amount of laboratory work that was necessary, the tests were restricted to the two characteristic steels referred to above. The Division submits this report at this time for approval and publication in the 1932 S.A.E. HANDBOOK as an appendix to the information on physical properties and heat-treatment of the Iron and Steel Specifications on pp. 473 and 474 in the 1931 S.A.E. HANDBOOK. The Division expects that as this method of charting physical properties becomes more thoroughly familiar to the industry as a whole, probability curves for other characteristic groups of S.A.E. Steels will be developed as much as possible from existing data and, where necessary, with the cooperation of steel manufacturers and users in making whatever further tests may be necessary.

(Proposed Addition to General Information)

PROBABILITY CURVES OF PHYSICAL PROPERTIES OF S.A.E. STEELS No. 3130 AND 6130

The present physical property charts for S.A.E. Steels have been carefully compiled by using the average minimum figures for tensile strength, yield-point, reduction of area and elongation as outlined on p. 473 of the 1931 S.A.E. HANDBOOK. The results are conservative and safe values to use under the conditions of size and heat-treatment as outlined.

Advancement in the science of designing and the art of heat-treatment has led to a demand for fuller information on the physical properties of steels. Due to the conservative nature of the present charts, individual tests usually show higher values than those indicated in the charts, which has led to a demand for further information. The Subdivision on Physical Property Charts that was appointed under the Iron and Steel Division of the

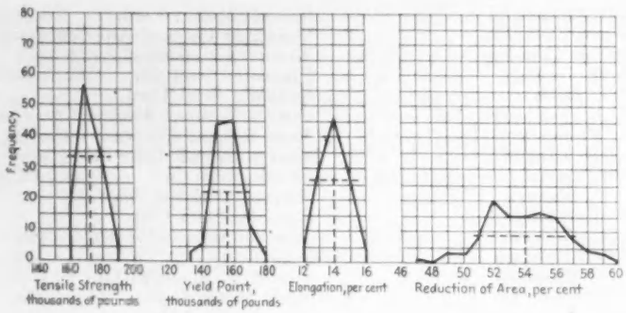


FIG. 1—EXAMPLE OF FREQUENCY CHARTS OF PHYSICAL CHARACTERISTICS OF 112 SAMPLES OF S.A.E. STEEL NO. 3130 USED IN TESTS

These Samples Were Drawn at 800 Deg. Fahr.

S.A.E. Standards Committee has studied the situation and believes that presenting the data as probability curves would be the more scientific method and give the added information desired.

The compilation of the curves consists in assembling the results of a large number of tests on a given steel, tabulating the results of the tests in groups of suitable ranges and plotting a curve with frequency of occurrence as ordinates and the group values as abscissas.

To eliminate unusual values that might occur due to the personal equation in heat-treatment, a positive and negative standard deviation is established by the following procedure:

Divide the planimetric area under the curve by the length of the base on which the curve rests, which length must be expressed in the same units as the area. This quotient gives the height of a rectangle constructed on the same base and having the same area as that enclosed under the curve. Construct this rectangle, and the points at which the upper side cuts the original curve will indicate the positive and negative standard deviations from the mean. This mean may be found by halving the range between the positive and negative standard deviations and erecting a vertical through that point intersecting the base. This range will be denoted by maximum and minimum values.

The maximum and minimum values and the value of greatest frequency for any drawing temperature are used as locating points in the probability curve. The curves as determined for S.A.E. Steels No. 3130 and 6130 are shown in Figs. 2 and 3.

Further detail of the tests on which these curves are based can be found in the S.A.E. JOURNAL, January, 1928, p. 55, for S.A.E. Steel No. 6130 and the December, 1931, issue, p. 480, for S.A.E. Steel No. 3130.

Malleable-Iron Castings

The proposed revision of the malleable-iron castings specification was approved by the Division at its meeting in Boston last September and is in accordance with the A.S.T.M. specification A47-30. In recommending this revision of the present Standard, the Division had in mind following the proposed new specification of the A.S.T.M. which includes a second grade of castings with higher tensile strength, but as these proposed specifications will not be

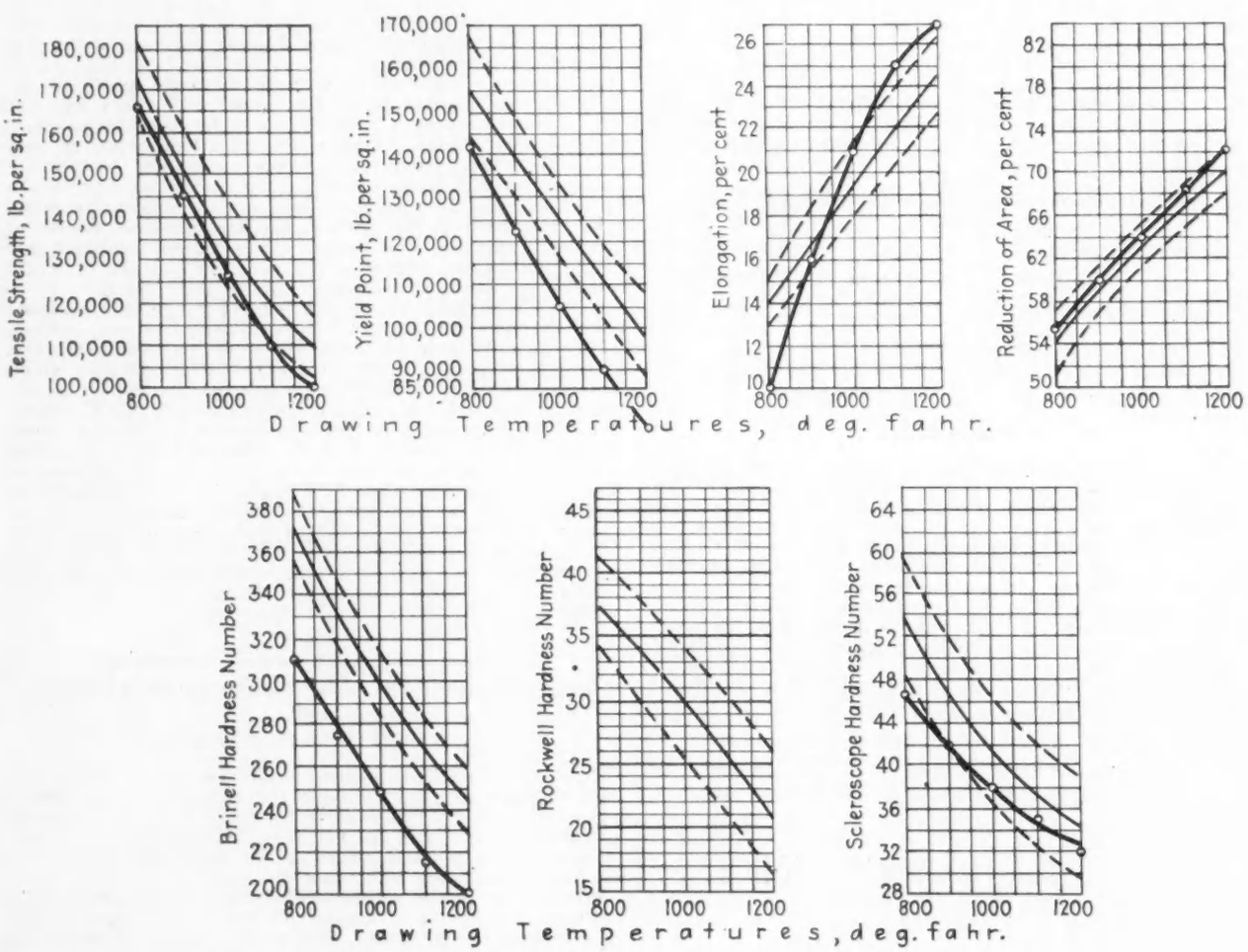

Tensile Strength, lb. per sq. in.
Yield Point, lb. per sq. in.
Elongation, per cent
Reduction of Area, per cent
Drawing Temperatures, deg. fahr.
Brinell Hardness Number
Rockwell Hardness Number
Scleroscope Hardness Number
Drawing Temperatures, deg. fahr.

FIG. 2—PROBABILITY CURVES OF PHYSICAL PROPERTIES OF S.A.E. STEEL NO. 3130

Maximum and Minimum Values Are Represented by the Dash-Line Curves, and Averages of the Tests of the Specimens Are Represented by Solid-Line Curves. These Values, as Abcissas, Were Plotted against the Frequency of Occurrence of Each Value as Ordinates. The Heavy Curves Are Those for This Steel, Quenched in Water (See p. 501 of the 1931 S.A.E. HANDBOOK)

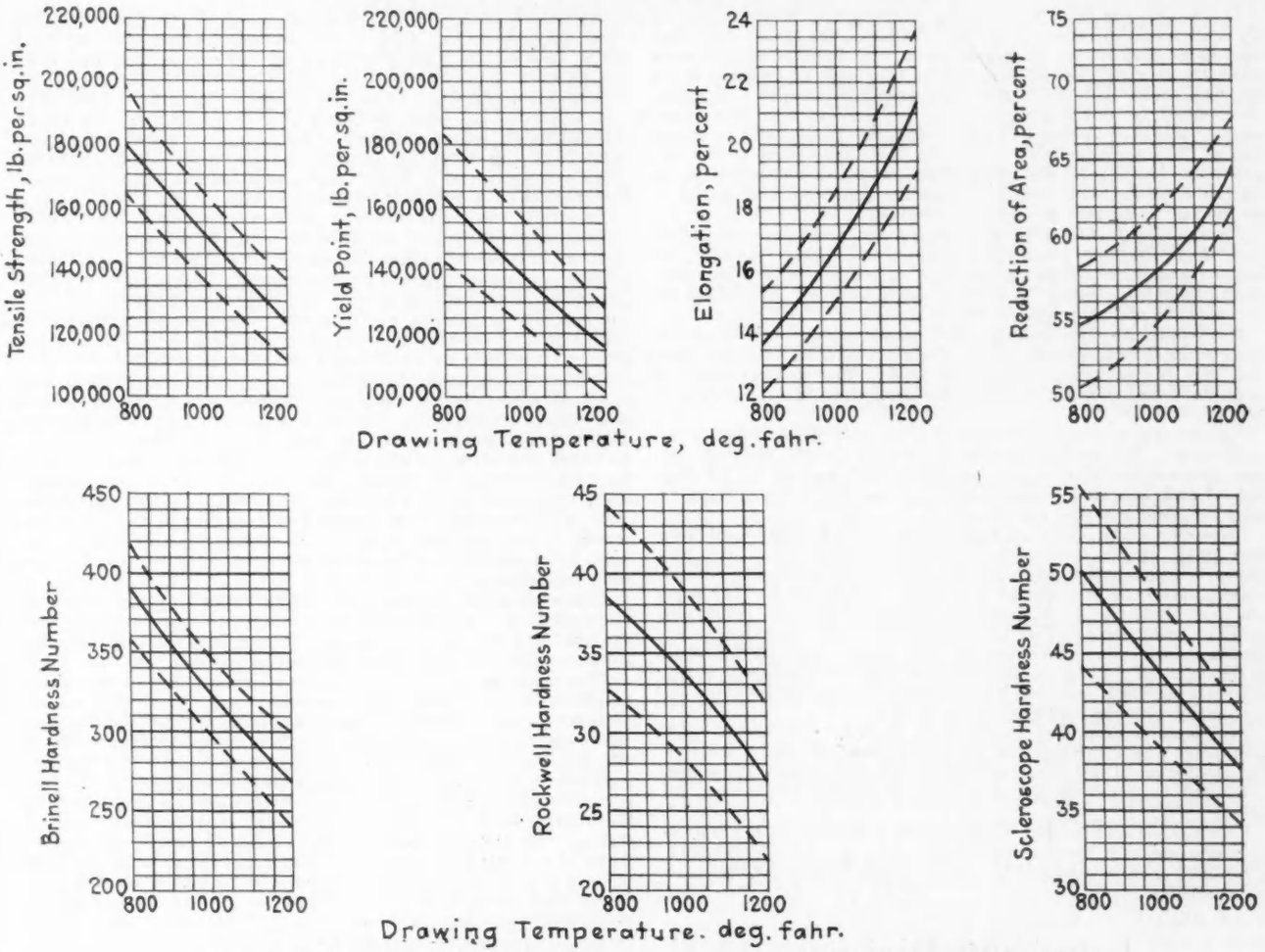

Tensile Strength, lb. per sq. in.
Yield Point, lb. per sq. in.
Elongation, per cent
Reduction of Area, per cent
Drawing Temperature, deg. fahr.
Brinell Hardness Number
Rockwell Hardness Number
Scleroscope Hardness Number
Drawing Temperature. deg. fahr.

FIG. 3—PROBABILITY CURVES OF PHYSICAL PROPERTIES OF S.A.E. STEEL NO. 6130

Maximum and Minimum Values Are Represented by the Dash-Line Curves, and Averages of the Tests of the Specimens Are Represented by Solid-Line Curves. These Values, as Abcissas, Were Plotted against the Frequency of Occurrence of Each Value as Ordinates

finally acted on by the A.S.T.M. until next June the accompanying report of the Division is submitted for adoption in revision of the present S.A.E. Standard commencing on p. 459 of the 1931 S.A.E. HANDBOOK. The changes in the present S.A.E. Standard involve the paragraphs relating to Manufacture and Tension Tests.

(Proposed Revision of S.A.E. Standard)

MALLEABLE-IRON CASTINGS[1]

Scope.—These specifications cover malleable-iron castings for railroad, motor-vehicle, agricultural-implement and general machinery purposes.

Manufacture.—The castings shall be produced by either the air-furnace, open-hearth, or electric-furnace process.

Tension Tests.—The tension test specimens specified shall conform to the following minimum requirements as to tensile properties:

Tensile Strength, lb. per sq. in.	50,000
Yield-Point, minimum, lb. per sq. in.	32,500
Elongation in 2 in., per cent	10.0

The yield-point may be determined by the drop of the beam of the testing machine or by the divider method.

Special Tests.—All castings, if of sufficient size, shall have cast thereon test lugs of a size proportional to the thickness of the casting, but not exceeding ⅝ x ¾ in. in cross-section. On castings that are 24 in. or over in length, a test lug shall be cast near each end. These test lugs shall be attached to the casting at such a point that they will not interfere with the assembling of the castings and may be broken off by the inspector.

If the purchaser or his representative so desires, a casting may be tested to destruction. Such a casting shall show good, tough malleable iron.

Tension-Test Specimens.—Tension-test specimens shall be of the form and dimensions shown in Fig. 1. Specimens whose mean diameter at the smallest section is less than 19/32 in. will not be accepted for test.

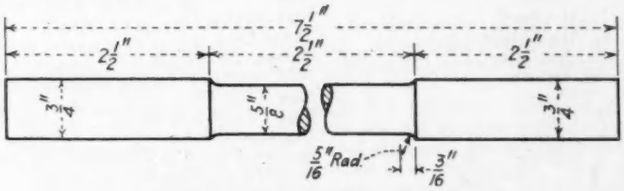


FIG. 1—TENSION-TEST SPECIMEN

A set of three tension-test specimens shall be cast from each melt, without chills, using heavy risers of sufficient height to secure sound bars. The specimens shall be suitably marked for identification with the melt. Each set of specimens so cast shall be placed in some one oven containing castings to be annealed.

Number of Tests.—After annealing, three tension-test specimens shall be selected by the inspector as representing the castings in the oven from which these specimens are taken.

[1] These specifications are in accord with the present A.S.T.M. Standard Specification for Malleable Castings A 47-30.

If the first specimen conforms to the specified requirements, or if, in the event of failure of the first specimen, the second and third specimens conform to the requirements, the castings in that oven shall be accepted, except that any casting may be rejected if its test lug shows that it has not been properly annealed. If either the second or third specimen fails to conform to the requirements, the entire contents of that oven shall be rejected. In case one of the retest specimens contains a flaw that results in the failure of the bar to meet the specifications, at the discretion of the inspector additional test specimens from the same oven may be tested or test specimens may be cut from castings.

Re-Annealing.—Any castings rejected for insufficient annealing may be re-annealed once. The re-annealed castings shall be inspected and if the remaining test lugs, or castings broken as specimens, show the castings to be thoroughly annealed, they shall be accepted; if not, they shall be finally rejected.

Workmanship.—The castings shall conform substantially to the patterns or drawings furnished by the purchaser, and also to gages that may be specified in individual cases. The castings shall be made in a workmanlike manner. A variation of ⅛ in. per ft. will be permitted.

Finish.—The castings shall be free from injurious defects.

Marking.—The manufacturer's identification mark and the pattern numbers assigned by the purchaser shall be cast on all castings of sufficient size, in such positions that they will not interfere with the service of the castings.

Inspection.—The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

The manufacturer shall be required to keep a record of each melt from which castings are produced, showing tensile strength and elongation of test specimens cast from such melts. These records shall be available and shown to the inspector whenever required.

Rejection.—Castings that show injurious defects subsequent to their acceptance at the manufacturer's works may be rejected, and, if rejected, shall be replaced by the manufacturer without charge to the purchaser.

Lubricants Division

PERSONNEL

E. W. Upham, *Chairman*	Chrysler Motors
H. C. Mougey, *Vice-Chairman*	General Motors Corp. Research Laboratories
Sydney Bevin	Tide Water Oil Co.
A. B. Boehm	Standard Oil Co. of N. J.
W. G. Clark	Pure Oil Co.
O. E. Eckert	Empire Refining Co.
J. B. Fisher	Waukesha Motor Co.
J. C. Geniesse	Atlantic Refining Co.
W. H. Graves	Packard Motor Car Co.
E. N. Klemgard	Shell Oil Co.
C. M. Larson	Sinclair Refining Co.
W. W. Lowe	Henry L. Doherty & Co.
J. L. McCloud	Ford Motor Co.
K. G. MacKenzie	Texas Co.
H. M. Northrup	Hudson Motor Car Co.
W. H. Oldacre	D. A. Stuart & Co., Ltd.
W. F. Parish	New York City
T. A. Peck	East Greenwich, R. I.
G. A. Round	Vacuum Oil Co.
H. J. Saladin	Standard Oil Co. (Indiana)
W. A. P. Schorman	British American Oil Co., Ltd.
F. D. Shields	Marathon Oil Co.
B. E. Sibley	Continental Oil Co.
C. W. Simpson	Cleveland Heights, Ohio
H. G. Smith	Gulf Refining Co.
J. B. Terry	Standard Oil Co. of California

Free-Wheeling Lubricant Viscosity Numbers

One of the most serious current problems that has faced the automobile manufacturers and the oil companies has been a classification of lubricants satisfactory for use in automobile free-wheeling mechanisms. When free-wheeling was introduced by automobile manufacturers they at first used lubricants with a wide range of properties but field experience soon showed that lubricants with certain properties were required to secure the best results. This led to the tendency for each company to develop its own lubricants specification which differed from those of other companies and that the situation would become very much confused was soon evident. Accordingly, the initial organized consideration of a solution of the problem in May, 1931, led to a meeting that was held in Detroit on Nov. 10 at which practically the entire automobile industry was represented. There agreement was reached that everything possible should be done toward standardizing lubricants for free-wheeling applications and that this simplification of the lubrication problem would equally benefit the petroleum industry. A second meeting was held on Nov. 11 in Chicago at the time of the American Petroleum Institute's convention which was also attended by technical representatives of a number of the oil companies and at this meeting a proposal to establish a definite classification of free-wheeling lubricants on a viscosity numbering system met with general approval. Following these meetings, another was held in Toronto, which was attended by representatives of oil companies as well as the Canadian Automobile Chamber of Commerce with representatives from all Canadian automobile companies, and the tentative specifications previously prepared by the American automobile manufacturers were agreed to.

The classification that was under consideration included lubricants falling within three ranges of viscosities specified at 100 and 210 deg. fahr., each classification for use above a specified climatic temperature.

The numbers that had been proposed for the three classifications of free-wheeling lubricants were No. 80 for use in temperatures above — 15 deg. fahr.; No. 90 in temperatures above 15 deg. fahr. and No. 110 in temperatures above 35 deg. fahr. Those who had taken part in these conferences felt that this classification should be given a definite neutral identification and accordingly the matter was referred to the Lubricants Division of the S.A.E. Standards Committee and to Subcommittee XXVII on Transmission Lubricants Classification of A.S.T.M. Committee D-2 on Petroleum Products and Lubricants, with the proposal that it be adopted as S.A.E. classification. A joint meeting of these Committees, which was also attended by representatives of automobile and oil companies not represented on them, was held in New York City on Nov. 23 and the proposals were presented and discussed thoroughly. The accompanying report was finally approved by majority votes of the members of the two Committees or their representatives who were present, the A.S.T.M. Subcommittee voting first. Subsequent to the meeting some of those who had voted in the minority indicated their desire to submit a minority report. The following recommendation that was voted on at the meeting on Nov. 23 was subject to confirmation by letter-ballot of the Lubricants Division members, at the time of printing, but was included in this issue of the S.A.E. JOURNAL to give it wide publicity prior to submitting it to the meeting of the S.A.E. Standards Committee on Jan. 25 and to the Society for adoption and publication in the 1932 S.A.E. HANDBOOK with the present S.A.E. numbering specifications for Crankcase Lubricants and Transmission and Rear Axle Lubricants.

The letter-ballot on the approval of the recommendation as voted at the joint meeting on Nov. 23 was not sent to the members of the Division until both the majority and minority reports had been received, in order that each member of the Division would have the complete information bearing on the recommendation in hand before he filed his letter-ballot, only Division members who are members of the Society being eligible to vote. The majority report and the minority report as provided for by Section V (f) of the Standards Committee Regulations, p. 665 of the 1931 S.A.E. HANDBOOK, follow.

MAJORITY REPORT DATED DEC. 7, 1931

Cars with free-wheeling units have been on the market for over a year and the number of cars with these units is rapidly increasing. When these cars were first introduced, the regular lubricants such as are satisfactory for rear axles were recommended for free-wheeling units, but it was soon found that lubricants with special properties were required to secure the best results. At first, each

automobile company using free-wheeling units developed lubricants that apparently took care of its particular requirements, but, since these specifications were developed independently, they all differed in various details, compelling the oil companies to carry a large number of lubricants differing slightly from each other. To help in clearing up this confusion and to reduce the number of lubricants that must be carried by service stations, a committee of the manufacturers supplying free-wheeling units and of cars equipped with such units was organized and in May, 1931, developed specifications for lubricants for free-wheeling units of all makes then in production. The two most important properties of the lubricants were found to be

(1) As high a viscosity as possible when the lubricant is warm, for the purpose of decreasing noise

(2) As low a viscosity as possible when the lubricant is cold to permit the lubricant to be squeezed out by the free-wheeling device, thus giving a positive drive

In developing these specifications a large number of lubricants were tested and the temperature at which slippage occurred with each lubricant was determined. The viscosities of all the lubricants were also determined at 100 deg. fahr. and at 210 deg. fahr. It was found that by extrapolating the viscosities using any of the viscosity-temperature charts, slippage with all these lubricants occurred at the same viscosity. Since different viscosity-temperature charts are not in agreement, the calculated numerical value for the viscosity at which slippage occurs will vary slightly, but the actual viscosity of the lubricant is of course the same regardless of which chart is used. Since lubricants from different crudes differ somewhat in the rate of change of viscosity with change of temperature, it was found necessary to specify the viscosity both at 210 deg. fahr. and at some lower temperature in order that the lubricant would have the desired viscosity both at high and at low temperatures. It is apparent that for any single temperature, lubricants properly refined from any crude could be selected so as to give equal performance. However, to meet the temperatures encountered in service without making it necessary for the car owner to require more than two lubricants in ordinary climates or more than three lubricants in extreme climates, it was found necessary to limit the free-wheeling lubricants to those having the least change in viscosity with change of temperature. Lubricants of this character will operate in free-wheeling units over a wider range of temperatures and a smaller number of lubricants are required to cover the temperatures encountered in service. To meet these conditions, specifications very similar to the three given below were developed.

During the Summer of 1931, free wheeling was adopted by other automobile companies. Since they had not had the experience in service with these units, they tried at first to use lubricants with a wider range of properties. They soon found, however, that to secure best results, lubricants with certain special properties were required. They adopted their own specifications and within a short time the confusion in regard to free-wheeling lubricants seemed to be as bad as it had been originally.

To overcome this confusion a meeting was held in Detroit on Nov. 10, 1931, at which practically the entire automobile industry was represented, whether they were using free wheeling or not. It was unanimously agreed that it was desirable to do everything possible to help standardize a classification for the free-wheeling lubricants that the manufacturers of free-wheeling cars and units had found to be necessary.

Since these free-wheeling lubricants were equally satisfactory for general use, in cars with or without the free-wheeling units, manufacturers of cars not using these units were in favor of the proposed classification. They felt that this simplification of the lubrication problem would permit the oil industry to supply the lubricants required by all automobile companies, and that if the existing confusion with which the oil industry had not been able to cope should not be corrected, their own lubrication requirements might suffer. The simplification of marketing and distributing these lubricants by oil companies was kept constantly in mind.

On Nov. 11, 1931, an informal meeting was held in Chicago during the meeting of the American Petroleum Institute, at which this problem was discussed with technical men representing the different oil companies. At both of these meetings the point was brought up that the names of these lubricants were of almost equal importance with the viscosity limits, for the following reasons:

(1) The name should be one that can be used generally in the entire Country so that all automobile companies, if they so desire, could use the same name for recommending lubricants of these viscosity limits regardless of the oil company supplying the lubricant.

(2) Since the viscosity limits of the free-wheeling lubricants are very narrow, lubricants with wider viscosity limits and automobile companies using lubricants with wider viscosity limits should not be subjected to any handicap in the use of the wider limits where they are satisfactory.

(3) The problem of carrying a sufficient number of lubricants to meet the different recommendations of the automobile companies is serious from the standpoint of the oil companies. By giving these specifications a number that will permit supplying them where the regular S.A.E. lubricants are recommended, it will be unnecessary for the small filling stations to carry the regular S.A.E. lubricants with a wider range of properties in addition to the free-wheeling lubricants, since the free-wheeling lubricants are a narrow range with narrow limits within the wider S.A.E. limits. In the case of large filling stations where the difference in price between lubricants with the narrow limits and those with the wider limits is important, the special free-wheeling lubricants could be carried for the free-wheeling units that require them, and regular S.A.E. No. 90, S.A.E. No. 110 and S.A.E. No. 160 for rear axles and other uses where the requirements are not as severe.

In recognition of the above facts the numbers that have been tentatively assigned to these free wheeling lubricants are 110, 90, and 80.

Similar meetings were held in Toronto with representatives of the oil companies, of the Canadian Automobile Chamber of Commerce and representatives of all the automobile companies. At the second of these meetings, held on Nov. 18, it was voted unanimously to adopt the proposed classification and recommend that it be submitted to the Society of Automotive Engineers and the American Society for Testing Materials for their approval.

The problem was then brought up before committees of the A.S.T.M. and the Society with the hope that these lubricants could be included in the present system of S.A.E. classification, which is now in such general use. It was felt that the only alternatives to such a procedure were to have the various automobile companies either go into the oil business themselves and supply the necessary lubricants or to have them recommend and guarantee the various lubricants by trade names. Both of these alternatives have proved to be wholly unsuitable as methods of making recommendations to dealers, the public and to the service divisions of the automobile manufacturers.

The specifications which are now in use for free-wheeling lubricants and which are being considered by the Society for standardization are printed on p. 17 of this section of the JOURNAL.

The viscosities at 210 deg. fahr. and 100 deg. fahr. for the No. 80 lubricant are given in a table, because there is too great a change in the factor by which the viscosity at 210 deg. fahr. must be multiplied to give the viscosity at 100 deg. fahr. for lubricants which will have the desired critical viscosity at —15 deg. fahr. In other words, the use of a table permits the use a much wider range of lubricants than would be possible if a single factor were used. For the lubricants in the other two classes, the factor changes so slightly that a table of viscosities is unnecessary.

It will be noted that these lubricants are classified in terms of viscosity. The requirements other than viscosity that are common to all three are given in the two paragrahps preceding the viscosity requirements.

In all cases it is stated that the lubricant must be a well-refined product and shall not contain any substance to build up an artificial viscosity. These requirements are to prevent non-uniformity in the most minute particles of the lubricant and to avoid the trouble and difficulty of determining the true viscosity of lubricants which have a false viscosity.

In all three specifications a minimum viscosity at 210 deg. fahr. is given with a provision by which the critical viscosity at which slippage occurs will not be exceeded at the temperature for which the lubricant is designed.

The subject of extreme pressure has not been mentioned as it was recognized that the methods of test for extreme pressure lubricants are not generally available at present. The classification is left open so as not to block any desirable development. This permits the use of extreme pressure lubricants in this classification if the purchaser and supplier are able to agree on the desirability of such lubricants and methods of testing. In this connection it should be pointed out that the system now under discussion is solely for the purpose of recommendations by automobile companies and oil companies to the public who buy lubricants for use in their own cars. These specifications should not be confused with purchasing agents specifications issued by large companies that have the facilities for making tests of various kinds.

Since the classification does not include all of the factors neces-

sary to determine quality, the purchaser buying these lubricants should deal with a company in which he has confidence, as quality of the lubricant in all cases is a matter that is left to the oil suppliers. This is in accord with present practice of the Society of Automotive Engineers in which lubricants are classified by viscosity with the quality depending upon the oil supplier. As an illustration, one of the properties in which the oil supplier is interested is the pour test of the lubricant. Pour test is not governed by the classification for several reasons.

(1) Pour test is one of the quality requirements of the lubricant and the oil supplier is responsible for the proper pour test just as he is responsible for the other quality requirements of the lubricant.

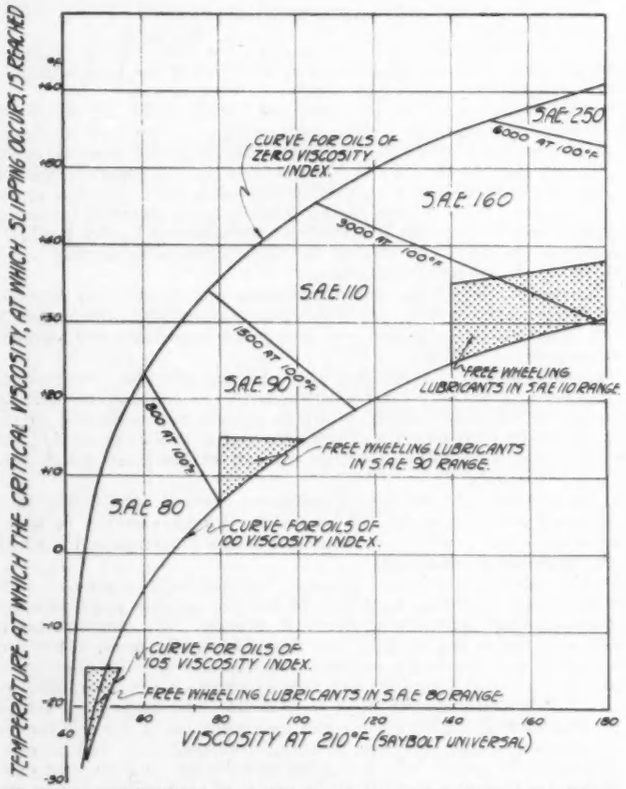
(2) Lubricants with pour tests that are not too far above the temperature at which they are designed to be used were found to give results that depended upon viscosity alone without any apparent effect due to the small differences in pour test. Since pour test is of minor importance in most cases, the men who developed this classification felt that the proper pour test could be left to the oil suppliers.

While the lubricants in the classifications are satisfactory from a lubrication standpoint for temperatures above the minimum for which they are designed, it was recognized that a lubricant with the highest viscosity when hot would be more satisfactory from a noise standpoint than the ones of lower viscosity.

The accompanying chart shows the relation between the viscosity of the lubricant at 210 deg. fahr., and the temperature at which the critical viscosity would be reached by decreasing the temperature of the lubricants. The critical viscosity is the viscosity at which slippage occurs. The upper line is the curve for lubricants of 0 viscosity index. The lower line is the curve for lubricants of 100 viscosity index. These values are taken from the viscosity values given by Dean and Davis[2]. All lubricants with the viscosity characteristics given by Dean and Davis will lie within the area bounded by the two curves. The areas covered by the present S.A.E. Transmission and Rear-Axle Viscosity Numbers are also shown on this chart. It will be noted that the free-wheeling lubricants for temperatures above —15 deg. fahr will be within the indicated area in the S.A.E. No. 80 range. In other words, these lubricants are the S.A.E. No. 80 Free-Wheeling Lubricants. In a similar manner, the lubricants for temperatures above +15 deg. fahr. lie within the indicated area in the S.A.E. No. 90 range. These are the S.A.E. No. 90 Free-Wheeling Lubricants. In the case of the lubricants for temperatures above +35 deg. fahr. it will be noted that most of them lie within the S.A.E. No. 110 range, but some of them lie within the S.A.E. 160 range. To prevent confusion in this matter it has been suggested that the notes bearing on this be added to the free-wheeling lubricant classification.

[2] See *Chemical and Metallurgical Engineering*, October, 1929, p. 616.

[3] Not a member of the Lubricants Division of the Standards Committee.



COMPARATIVE VISCOSITY RANGES OF THE PROPOSED FREE-WHEELING LUBRICANTS AND THE S.A.E. TRANSMISSION AND REAR-AXLE LUBRICANTS

Since low temperatures arrive earlier in Canada than in most of the United States, the classification is now in use by the entire oil and automobile industry of Canada. In the automobile industry in the United States the manufacturers of cars with free-wheeling units are also using the classification. The automobile companies not now using free-wheeling units have agreed to the classification to help the entire automobile and oil industry and to reduce to the minimum the number of lubricants that must be carried by the oil companies.

It is recognized that the customers of the automobile industry are also customers of the oil industry and that when a person purchases a car he virtually commits himself to the purchase of a large amount of the products of the oil industry. Only by cooperation of the oil industry and the automobile industry can these mutual problems be solved.

W. S. JAMES,[3]
Chairman, Special Committee of Automotive Manufacturers on Free-Wheeling Lubricants (Studebaker Corp.)

E. W. UPHAM,
Chairman, Lubricants Division, S.A.E. Standards Committee (Chrysler Corp.)

H. C. MOUGEY,
Chairman, Sub-Committee XXVII on Transmission Lubricants Classification of the American Society for Testing Materials Committee D-2 on Petroleum Products and Lubricants (General Motors Corp. Research Laboratories.)

MINORITY REPORT DATED DEC. 15, 1931

The undersigned members of the Lubricants Division very greatly appreciate the work accomplished by the automotive manufacturers using free-wheeling equipment in coordinating the very large number of present specifications into three specifications. We feel that the preparation and promulgation of these specifications will be of very great assistance to the oil industry in the preparation of suitable lubricants. We do feel, however, that formal adoption of these specifications by the Society of Automotive Engineers as a recommended practice for viscosity numbers for oils for free-wheeling transmissions is most inadvisable at present.

The cooperation between the Society and the oil industry in the preparation and adoption of the recommended practice for viscosity numbers for crankcase oils and transmission lubricants has been whole-hearted. Without this cooperation the present general acceptance and use by the consuming trade would have been impossible.

Viscosity numbers of crankcase oils and transmission lubricants are strictly classifications and in no way limit the source from which oils in these classifications can be secured. The proposed classifications for viscosity numbers for free-wheeling mechanisms are not classifications but restrictive specifications, since oils to meet them must for all practical purposes be obtained from one definite source, representing but a small percentage of the crude oil produced in this Country.

No supporting data were furnished to the Lubricants Division to justify the proposed specifications. The proponents of the specifications advance three arguments:

(1) That the oils covered by these specifications are absolutely necessary for the lubrication of roller-type free-wheeling transmissions.

(2) That the adoption of these specifications by the Society will eliminate the need of approved lists issued by automotive manufacturers and will substitute S.A.E. viscosity numbers.

(3) That the adoption of these specifications by the Society will assure the car owner receiving the oil or oils that the manufacturer believes are necessary.

The answers to these arguments are

(1) No single specification for a universal lubricant for free-wheeling mechanisms has been advanced. Three

specifications are proposed with minimum operating limits of —15 deg. fahr., +15 deg. fahr. and +35 deg. fahr. It was admitted at the meeting of the Division on Nov. 23 that oils meeting these specifications might not be absolutely necessary but that if the specifications were changed to admit oils from other sources, the result would be either:

(*a*) The proposed specifications would be thrown outside the present S.A.E. classification for transmissions oils

(*b*) It would require raising of the minimum temperature limits very slightly.

(2) We feel that the disadvantages involved in immediate adoption of these specifications by the Society far outweigh any slight advantage in the elimination of approved lists.

(3) It will be a physical impossibility for the average car owner to change oils to keep within the temperature ranges specified for the three different grades as atmospheric temperatures vary from day to day. Consequently, the adoption of these specifications by the Society will not insure the car owner having the correct oil at all times.

Further arguments against immediate adoption of the proposed specifications are

(1) Standardization at present is highly inadvisable since free-wheeling is relatively new and in a state of rapid change and improvement.

(2) It is unfair and unwise to establish as an S.A.E. Standard a specification admittedly made highly restrictive to meet the needs of the worst operating condition of of a specific type of free-wheeling, when products from various sources work satisfactorily in the latest designs and in the old designs at temperatures slightly higher than the limits established.

(3) Special lubricants are not required except for the roller type of free-wheeling transmission.

(4) If the free-wheeling numbers are adopted, the tendency will be to recommend these restricted oils for transmissions and axles generally to eliminate the need for multiple recommendations for gear lubrication.

(5) The proposed standard would, for many refiners both large and small, involve the addition to an already large number of grades of from one to three new products selling at higher prices to meet a very limited demand. At a time when every effort is being made to reduce the number of grades to be stocked and distributed, this constitutes an unwarranted hardship from a marketing standpoint and is a step in the wrong direction leading to greater expense and confusion in the field.

(6) It has always been the practice of the Society to set up standards only after due deliberation and consideration, never on the basis of a limited and transitory need. In this instance the specifications were adopted by the motor-car manufacturers involved on Nov. 12, submitted to the Lubricants Division on Nov. 17 and considered by the Division on Nov. 23, with the object of having the specifications adopted by the Society at the Annual Meeting in January.

As previously indicated, the need for free-wheeling oils is limited to a definite design of free-wheeling transmissions, and to only a part of the units using this design. It is also admitted that marked improvements will soon eliminate the need for special lubricants.

In view of the foregoing it would seem obvious that no standard or recommended practice for free-wheeling lubricants should be adopted at this time.

O. E. Eckert[4]
(Empire Refining Co.)
E. M. Klemgard
(Shell Oil Co.)
W. W. Lowe
(Henry L. Doherty & Co.)
K. G. Mackenzie
(Texas Co.)
R. E. Wilson[4]
(Standard Oil Co. of Indiana)
H. J. Saladin
(Standard Oil Co. of Indiana)
F. D. Shields[5]
(Marathon Oil Co.)
B. E. Sibley
(Continental Oil Co.)
J. B. Terry
(Standard Oil Co. of California)
G. A. Round
(Vacuum Oil Co.)

[4] Formerly a member of the Lubricants Division.
[5] Non-voting member of Lubricants Division.

The recommendation is therefore submitted subject to final confirmation by Division letter-ballot, for adoption as S.A.E. Recommended Practice.

(Proposed S.A.E. Recommended Practice)

The S.A.E. Viscosity Numbers for Free-Wheeling Lubricants constitutes only a classification in terms of viscosity and of consistency at low temperatures. Other factors of quality or character are not considered.

S.A.E. Viscosity No.	80 F.W.	90 F.W.	110 F.W.
Consistency, Must Not Channel in Service at Deg. Fahr.	—10	0	+10

These lubricants must be well-refined products which shall not contain any substance to build up an artificial viscosity. No fillers or abrasives such as talc, pulp, cork, Fuller's earth, graphite, mica, asbestos, etc., shall be permitted.

S.A.E. NO. 80 F.W.—FREE-WHEELING TRANSMISSION LUBRICANT FOR USE IN TEMPERATURES ABOVE —15 DEG. FAHR.

The viscosity of this lubricant at 210 deg. fahr. shall not be less than 45 sec. Saybolt. The viscosity at 100 deg. fahr. shall not be greater than that given in the following table.

Viscosity at 210 Deg. Fahr.	Maximum Viscosity at 100 Deg. Fahr.
45	203
46	215
47	227
48	239
49	251
50	263
51	275
52	287
53	299
54	311

S.A.E. NO. 90 F.W.—FREE-WHEELING TRANSMISSION LUBRICANT FOR USE IN TEMPERATURES ABOVE +15 DEG. FAHR.

The viscosity of this lubricant at 210 deg. fahr. shall not be less than 80 sec. Saybolt. The viscosity at 100 deg. fahr. shall not be greater than 12 times the viscosity at 210 deg. fahr.

S.A.E. NO. 110 F.W.—FREE-WHEELING TRANSMISSION LUBRICANT FOR USE IN TEMPERATURES ABOVE +35 DEG. FAHR.

The viscosity of this lubricant at 210 deg. fahr. shall not be less than 140 sec. Saybolt. The viscosity at 100 deg. fahr. shall not be greater than 20 times the viscosity at 210 deg. fahr.

Notes on F.W. Lubricants Classification.—Lubricants which are normally classified as S.A.E. No. 160 but which are also within the limits for S.A.E. No. 110 F.W. may be classified by the supplier as meeting any or all of the following S.A.E. viscosity ranges: S.A.E. No. 160, S.A.E. No. 110 and S.A.E. No. 110 F.W.

The free-wheeling lubricants are within the viscosity limits of the corresponding S.A.E. viscosity ranges but in addition have other properties essential for the successful operation of the free-wheeling unit.

For example, while S.A.E. No. 90 F.W. may be used where S.A.E. No. 90 is specified, S.A.E. No. 90 cannot be used where S.A.E. No. 90 F.W. is required.

Motorcoach and Motor-Truck Division

PERSONNEL

A. W. Herrington, *Chairman*	Marmon-Herrington Co.
A. Gelpke, *Vice-Chairman*	Autocar Co.
W. J. Baumgartner	Relay Motors Corp.
M. C. Horine	International Motor Co.
G. B. Ingersoll	Federal Motor Truck Co.
L. C. Josephs, Jr.	International Motor Co.
F. W. Kateley	American Car & Foundry Motors Co.
W. F. Klein	General Motors Truck Co.
A. A. Lyman	Public Service Coordinated Transport
J. A. Packard	Studebaker Corp.
L. H. Palmer	Fifth Avenue Coach Co.
A. J. Scaife	White Co.
E. M. Schultheis	Timken Roller Bearing Co.
P. V. C. See	Akron Transportation Co.
T. C. Smith	American Telephone & Telegraph Co.
E. M. Sternberg	Sterling Motor Truck Co.

Motor-Truck Chassis Dimensions

At the meeting of the Society at White Sulphur Springs last June, *CA* dimensions, from extreme rear of cab to centerline of rear axle, for four-wheel motor-trucks were adopted as published on p. 56 of the July Supplement to the 1931 S.A.E. HANDBOOK. The question was raised at that time regarding similar dimensions for six-wheel trucks that are coming into considerable use. Accordingly the Subdivision on Motor-Truck Chassis Dimensions, of which J. F. Winchester is chairman, took up with the motor-truck manufacturers the standardization of these dimensions for six-wheel trucks and presented its report at the meeting of the Subdivision in Atlantic City on Sept. 29. Discussion of various methods of establishing the *CA* dimensions with respect to the two rear axles resulted in the accompanying recommendation which was accordingly submitted by letter-ballot to the members of the Motorcoach and Motor-Truck Division, the result being an almost unanimous approval. The accompanying report is therefore recommended for adoption to supplement the present S.A.E. specification.

(Proposed Addition to S.A.E. Recommended Practice)

The *CA* dimension of six-wheel motor-trucks shall be the same as those for four-wheel trucks and shall be measured from the extreme back-of-cab to a line midway between the two rear axles and shall be expressed as a hyphenated figure, the first unit of which shall be the standard *CA* dimension as above defined. The second unit shall be the distance between the two rear axles and is to be given by the vehicle manufacturer as information only.

Chassis-Record Form

About four years ago a Subcommittee was organized by the Operation and Maintenance Committee of the Society, now the Transportation and Maintenance Activity Committee, to draft a standard form for adoption and publication as S.A.E. Recommended Practice that would serve as a record of each chassis delivered and facilitate the securing of service and replacement parts by the vehicle operator. The first form was circularized to motor-truck operators and manufacturers in March, 1929, but, due partly to the large number of items included, the proposal met with divided opinion as to its usefulness and acceptability. Study was given to the criticisms submitted and to the possibility of further simplifying the form to meet these criticisms and a new report was circularized and then discussed at a meeting held at Atlantic City in October, 1929. Still further suggestions were considered for simplifying the report and a new draft discussed at a meeting of the Transportation and Maintenance Activity Committee during the Semi-Annual Meeting of the Society last June. Many of those who had previously disapproved the report felt that a simplified form would be acceptable and desirable and accordingly after further simplification, the accompanying form was approved at a joint meeting of the Transportation and Maintenance Activity and the Motorcoach and Motor-Truck Activity Committees at Atlantic City on Sept. 28, and subsequently submitted to the Motorcoach and Motor-Truck Division for approval by letter-ballot of the Division members. The ballot resulted in almost unanimous approval of the recommendation which is submitted for adoption by the Society as S.A.E. Recommended Practice. This form, if approved, will be included in the 1932 S.A.E. HANDBOOK and published later in separate form in the same way that the S.A.E. Engine-Testing Forms are printed, if the demand for it warrants.

MOTOR-TRUCK CHASSIS-RECORD FORM

Order No. .....
Model No. .....
Chassis No. .....
Wheelbase, in. .....
Back of Cab to Center of Rear Axle, in. .....

Weight Distribution
Front Wheels, per cent .....
Rear Wheels, per cent .....

Chassis Weight, lb. .....
Body Weight, lb. .....
Payload Weight, lb. .....
Gross Weight, lb. .....

UNIT	DESCRIPTION
ENGINE	
Make	
Model	
Serial No.	
Number of Cylinders	
Bore and Stroke, in.	
Cylinder-Head Type	
Cylinder-Head Gasket Thickness	
Spark-Plugs, Size and Type	
Valve Stem Diameter—Inlet	
Exhaust	
Valve Guide Bushing—Inlet	
Exhaust	
Pistons, Make and Type	
Material	
Clearance at Top, in.	
Clearance at Skirt, in.	
Piston Pins Diameter, in.	
Clearance, in.	
Piston Rings, Make	
Number of Compression Rings	
Size and Clearance	
Number of Oil Rings	
Size and Clearance	
GOVERNOR	
Make and Type	
Part or Serial No.	
Setting Recommended	
Speed, r.p.m.	
FUEL SYSTEM	
Tank Capacity	
Over-All Dimensions, in.	
Location	
Gasoline Gage, Make and Type	
Vacuum Tank, Make and Type	
Fuel Pump, Make and Type	
Carbureter, Make	
Model and Type	
Size, in.	
Air Cleaner, Make	
Model and Type	
EXHAUST SYSTEM	
Muffler, Make and Type	
COOLING SYSTEM	
Radiator, Make and Type	
Capacity	
Radiator Shutters	
Fan Type	
Belt Type	
Water Pump Type	
OILING SYSTEM	
Pressure Gage	
Chassis Lubrication Type	
Oil Filter, Make and Type	
Rectifier, Type	
ELECTRIC SYSTEM	
Magneto, Make and Type	
Impulse Starter, Type	
Magneto Coupling, Type	

UNIT	DESCRIPTION
ELEC. SYSTEM (*Concluded*)	
Generator, Make and Type	
Voltage	
Cut-Out, Make and Type	
Unit with Regulator?	
Starting Motor, Make and Type	
Voltage	
Starter Switch	
Drive	
Battery, Make and Type	
Voltage-Ampere Hours	
Over-All Dimensions	
Distributor, Make and Model	
Spark Coil, Make	
Ammeter, Make	
Ignition Switch, Make	
Head-Lamps, Make and Type	
Lens, Make and Type	
Size, in.	
Stoplight, Make	
Fuses, Size	
CLUTCH	
Make and Type	
Number of Driving Discs	
Number of Driven Discs	
Release Bearing, Make	
Type and Size	
Pilot Bearing, Make	
Type and Size	
TRANSMISSION	
Make and Type	
Auxiliary Transmission	
Fitted for Power Take-Off?	
DRIVE	
Propeller Shaft, Long	
Length Over All, in.	
Universal Joints, Make	
Propeller Shaft Center Bearing	
Make and Type	
Propeller Shaft, Short	
Length Over All, in.	
Universal Joints, Make	
Sprockets, Number of Teeth	
Front	
Rear	
Drive Chains, Make and Type	
Size, in.	
Jackshaft, Assembly No.	
Gear Ratio	
CONTROL	
Steering-Gear Assembly	
Make	
Type	
FRONT AXLE	
Assembly, Part No.	
Wheels, Make and Type	
Tires, Make and Type	
Size	

UNIT	DESCRIPTION
FRONT AXLE (*Concluded*)	
Rim, Type	
Wheel Bearings, Make	
Inner	
Outer	
Hub Assembly, Type	
REAR AXLE	
Assembly, Part No.	
Wheels, Make and Type	
Tires, Make and Type	
Size	
Rim, Type	
Wheel Bearings, Make	
Inner	
Outer	
Hub Assembly, Type	
Differential, Type	
Differential Housing, No.	
Type	
Gear Ratio	
FRAME	
Make and Serial No.	
Special Members	
BRAKES	
Foot Brakes, Make and Type	
Hand Brakes, Make and Type	
SPRINGS	
Front, Make and Type	
Rear, Make and Type	
Helper Springs	
ODOMETER	
Hubodometer, Make and Type	
Speedometer, Make and Type	
Pinion Gear	
Swivel Joint	
Drive Gear	
Shaft	
Elbow	
Adapter	
Odometer Shaft	
Length, in.	
Driven from	
BODY	
Cab, Make and Type	
Body, Make and Type	
EQUIPMENT	
Hoist, Make and Type	
Power Take-Off	
Power Take-Off Mounting	
Tire Pump, Make	
Winch, Make and Type	
Capacity	
Driving Tower Assembly	
Shock-Absorbers, Make	
Horn	

Describe Any Unusual Features

Screw-Threads Division

PERSONNEL

E. H. Ehrman, *Chairman*	Standard Screw Co.
Earle Buckingham, *Vice-Chairman*	Massachusetts Institute of Technology
A. Boor	Willys-Overland Co.
E. J. Bryant	Greenfield Tap & Die Corp.
G. Carvelli	Wright Aeronautical Corp.
G. S. Case	Lamson & Sessions Co.
C. T. Doman	H. H. Franklin Mfg. Co.
R. M. Heames	Victor Peninsular Division of the Allied Products Corp.
W. E. John	Sterling Engine Co.
W. J. Outcalt	General Motors Corp.
L. L. Roberts	Packard Motor Car Co.
F. W. Stein	Fairbanks, Morse & Co.
S. B. Terry	Pratt & Whitney Co. Division of the Niles-Bement-Pond Co.
O. B. Zimmerman	International Harvester Co.

High Nuts

The Division at its meeting last May recommended that all S.A.E. Standard Hexagon Slotted Nuts, both regular and high, be revised so that the slots will conform to the S.A.E. Recommended Practice for Slots in Plain Nuts that was adopted by the Society in June of this year and printed on p. 55 of the July Supplement to the 1931 S.A.E. HANDBOOK. As the S.A.E. Standard for High Nuts, p. 399 of the 1931 S.A.E. HANDBOOK, is the only present S.A.E. specification that does not conform to these nut-slot dimensions, the Division now recommends that this standard be revised accordingly to specify the dimensions given below.

(Proposed Revision of S.A.E. Standard)

Nut Size *A*	Slot Width *F*	Slot Depth *G*
1/4	5/64	3/32
5/16	5/64	7/64
3/8	1/8	1/8
7/16	1/8	9/64
1/2	1/8	11/64
9/16	5/32	11/64
5/8	5/32	13/64
3/4	5/32	7/32
7/8	5/32	1/4
1	5/32	9/32

Tire and Rim Division

PERSONNEL

H. M. Crane, *Chairman*	General Motors Corp.
W. R. Griswold, *Vice-Chairman*	Packard Motor Car Co.
C. S. Ash	Kelsey-Hayes Wheel Corp.
R. S. Begg	Midland Steel Products Co.
C. E. Bonnett	Tire & Rim Association, Inc.
C. C. Carlton	Motor Wheel Corp.
B. Darrow	Goodyear Tire & Rubber Co.
E. E. Dearth	Fisk Rubber Co.
J. E. Hale	Firestone Tire & Rubber Co.
F. W. Hertrich	Buick Motor Co.
F. M. Holden	Pontiac, Mich.
H. W. Kranz	Cleveland Welding Co.
B. J. Lemon	United States Rubber Co.
E. S. Marks	H. H. Franklin Mfg. Co.
W. B. Minch	Kelsey-Hayes Wheel Corp.
G. E. Parker	Cadillac Motor Car Co.
A. J. Scaife	White Co.
K. D. Smith	B. F. Goodrich Rubber Co.
J. G. Swain	Goodyear Tire & Rubber Co., Inc.
C. P. Thomas	Reo Motor Car Co.
L. Thoms	Graham-Paige Motors Corp.
F. E. Watts	Hupp Motor Car Corp.
B. F. Wright	Dodge Bros. Corp.
R. B. Wuerfel	Chevrolet Motor Co.

Tire and Rim Sizes

During the year the Tire & Rim Association, Inc., has at various times adopted changes affecting the tire and rim standards of the Society and to have these specifications uptodate in the 1932 S.A.E. HANDBOOK, the Association was asked to indicate what changes should be considered by the Division in the S.A.E. specifications. The following additions to the table of rim sizes used on standard tires on passenger cars, which is printed on p. 404 of the 1931 S.A.E. HANDBOOK were furnished the Society and referred to the Division for its approval by letter-ballot. As this was the only subject to be acted on at the time calling a meeting of the Division was deemed unnecessary. The following additions to the present standard are therefore recommended for adoption and publication in the 1932 S.A.E. HANDBOOK. The revision constitutes the addition of the 4.25 and the 4.50 tire sections with their corresponding drop-center rims and the addition of the 4.19 *F* and 4.37 *F* drop-center rim-dimensions for the present 7.50 tire section.

(Proposed Addition to S.A.E. Standard)

	Drop-Center Rims				
Tire Section	Rim Size	Flange Height	Width	Well	Ledge
4.25	2.50 *D*	*D* (0.664)	2.50	0.560	0.53
4.50	2.75 *D*	*D* (0.664)	2.75	0.560	0.59
7.50	4.19 *F*	*F* (0.828)	4.19	0.96	0.87
7.50	4.37 *F*	*F* (0.828)	4.37	0.88	0.87